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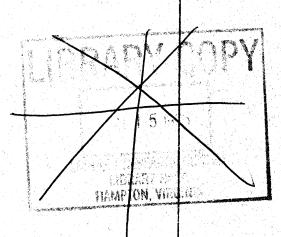
## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

#### REPORT 1135

# EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

By AMES RESEARCH STAFF





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Ames Aeronautical Laboratory

Moffett Field, Calif.

## National Advisory Committee for Aeronautics

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Conduct, under unified control, for all agencies, of scientific research on the fundamental problems of flight

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## REPORT 1135

## EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW 1

By AMES RESEARCH STAFF

#### **SUMMARY**

This report, which is a revision and extension of NACA TN 1428, presents a compilation of equations, tables, and charts useful in the analysis of high-speed flow of a compressible fluid. The equations provide relations for continuous one-dimensional flow, normal and oblique shock waves, and Prandtl-Meyer expansions for both perfect and imperfect gases. The tables present useful dimensionless ratios for continuous one-dimensional flow and for normal shock waves as functions of Mach number for air considered as a perfect gas. One series of charts presents the characteristics of the flow of air (considered a perfect gas) for oblique shock waves and for cones in a supersonic air stream. A second series shows the effects of caloric imperfections on continuous one-dimensional flow and on the flow through normal and oblique shock waves.

#### INTRODUCTION

The practical analysis of compressible flow involves frequent application of a few basic results. A convenient compilation of equations, tables, and charts embodying these results is therefore of great assistance in both research and design. The present report makes one of the first such compilations (ref. 1) more readily available in a revised and extended form. The revisions include a complete rewriting of the lists of equations, as well as the correction of certain typographical errors which appeared in the earlier work. The extensions are primarily in the directions dictated by increasing flight speeds, that is, to higher Mach numbers and to higher temperatures with the accompanying gaseous imperfections.

Compilations similar to those of reference 1 have been given in other publications, as, for example, references 2 through 6. These references have been utilized in extending the tables and charts to higher values of the Mach number. The extension to imperfect gases is based on the relations presented in references 7 and 8.

## SYMBOLS AND NOTATION PRIMARY SYMBOLS

A

speed of sound cross-sectional area of stream tube or channel

α	normal-force coefficient for cones normal force
$C_{N}$	normal-force coefficient for cones, $\frac{\text{normal force}}{q_{\infty}S_b}$
$c_p$	specific heat at constant pressure
$c_v$	specific heat at constant volume
h	enthalpy per unit mass, $u+pv$
l	characteristic reference length
M	Mach number, $\frac{V}{a}$
p	pressure <sup>2</sup>
q	dynamic pressure, $ hoV^2/2$
q	heat added per unit mass
R	gas constant
R	Reynolds number, $\frac{\rho V l}{\mu}$
$S_b$	base area of cone
8	entropy per unit mass
T	absolute temperature <sup>2</sup>
u	internal energy per unit mass
v	specific volume, $\frac{1}{\rho}$
u,v	velocity components parallel and perpendicular respectively, to free-stream flow direction
$ ilde{u}, \  ilde{v}$	velocity components normal and tangential, respectively, to oblique shock wave
V	speed of flow
V <sub>m</sub>	maximum speed obtainable by expanding to zero absolute temperature
w	external work performed per unit mass
$\alpha$	angle of attack
β	$\sqrt{ M^2-1 }$
γ	ratio of specific heats, $\frac{c_p}{c_p}$
δ	angle of flow deflection across an oblique shock wave
$\theta$	shock-wave angle measured from upstream flow direction
θ	molecular vibrational-energy constant
μ	Mach angle, $\sin^{-1}\frac{1}{M}$
$\mu$	absolute viscosity
ν	Prandtl-Meyer angle (angle through which a
	gunorgania atmagna in tar.

supersonic stream is turned to expand from

M=1 to M>1

Supersedes NACA TN 1428, "Notes and Tables for Use in the Analysis of Supersonic Flow" by the Staff of the Ames 1- by 3-foot Supersonic Wind-Tunnel Section, 1947. When used without subscripts, p,  $\rho$ , and T denote static pressure, static density, and static temperature, respectively.

ξ	pressure ratio across a shock wave, $\frac{p_i}{p_i}$
ρ σ	mass density <sup>2</sup> semivertex angle of cone
	SUBSCRIPTS

$\infty$	free-stream conditions
1	conditions just upstream of a shock wave
2	conditions just downstream of a shock wave
t	total conditions (i. e., conditions that would
	exist if the gas were brought to rest isentropically)
*	critical conditions (i. e., conditions where the local speed is equal to the local speed of sound)
c	conditions on the surface of a cone
r	reference (or datum) values
perf	quantity evaluated for a gas which is both ther-
	mally and calorically perfect
thorm part	quantity explicated for a god which is the servelle

therm perf quantity evaluated for a gas which is thermally perfect but calorically imperfect

( )<sub>p</sub> derivative evaluated at constant pressure ( )<sub>s</sub> derivative evaluated at constant entropy

()<sub>T</sub> derivative evaluated at constant temperature derivative evaluated at constant specific volume

()<sub>rev</sub> quantity evaluated over a reversible path

#### NOTATION

The notation in brackets [ ] after many of the equations signifies that the equation is valid only within certain limitations. For example:

[perf] means that the equation is restricted to a gas which is both thermally and calorically perfect. (By "thermally perfect" it is meant that the gas obeys the thermal equation of state  $p=\rho RT$ . By "calorically perfect" it is meant that the specific heats  $c_p$  and  $c_v$  are constant.)

[therm perf] means that the only restriction on the gas is that it must be thermally perfect. Equations so marked may be used for calorically imperfect gases. (They are, of course, also valid for completely perfect gases.)

[isen] means that the flow process must take place isentropically. Equations so marked may not be applied to the flow across a shock wave.

[adiab] means that the only restriction on the flow process is that it must take place adiabatically—that is, without heat transfer. (Such a flow process may or may not be isentropic depending on whether it is or is not reversible.) Equations so marked may be applied to the flow across a shock wave.

An equation without notation has no restrictions beyond those basic to the study of thermodynamics and/or inviscid compressible flow.

#### FUNDAMENTAL RELATIONS

#### **THERMODYNAMICS**

#### THERMAL EQUATIONS OF STATE

A thermal equation of state is an equation of the form

$$p = p(v, T) \tag{1}$$

Several of the more commonly used thermal equations of state are the following:

Equation for thermally perfect gas

$$p = \frac{RT}{v} = \rho RT \text{ [therm perf]}$$
 (2)

or

$$\frac{dp}{p} - \frac{d\rho}{\rho} - \frac{dT}{T} = 0 \text{ [therm perf]}$$
 (3)

Equations for thermally imperfect gas

Van der Waals' equation (ref. 9)

$$p = \frac{RT}{v - b} - \frac{a}{v^2} \tag{4}$$

where a is the intermolecular-force constant and b is the molecular-size constant (see ref. 9, pp. 390 et seq. for numerical values).

Berthelot's equation (ref. 7)

$$p = \frac{RT}{v - b} - \frac{c}{v^2 T} \tag{5}$$

where b is the molecular-size constant and c is the intermolecular-force constant (see ref. 7 for numerical values).

Beattie-Bridgeman equation (ref. 10)

$$p = \frac{RT}{v^2} \left( 1 - \frac{c}{vT^3} \right) \left[ v + B_0 \left( 1 - \frac{b}{v} \right) \right] - \frac{A_0}{v^2} \left( 1 - \frac{a}{v} \right)$$
 (6)

where a,  $A_0$ , b,  $B_0$ , and c are constants for a given gas (see ref. 10, p. 270 for numerical values).

#### CALORIC EQUATION OF STATE

A caloric equation of state is an equation of the form

$$u = u(v, T) \tag{7}$$

It can be shown that

$$du = c_v dT + \left[ T \left( \frac{\partial p}{\partial T} \right)_v - p \right] dv \tag{8a}$$

$$du = c_v dT$$
 [therm perf] (8b)

If the gas is calorically perfect—that is, the specific heats are constant—equation (8b) can be integrated to obtain

$$u = c_{\mathbf{r}}T + u_{\mathbf{r}} \quad [perf] \tag{9}$$

<sup>&</sup>lt;sup>2</sup> When used without subscripts, p,  $\rho$ , and T denote static pressure, static density, and static temperature, respectively.

#### ENERGY RELATIONS

The law of conservation of energy gives

$$\left. \begin{array}{ll} d\,q\!=\!du\!+\!dw & \text{(first law of thermodynamics)} \\ =\!du\!+\!p\;dv\!=\!dh\!-\!v\;dp \end{array} \right\} \quad (10a)$$

#### SPECIFIC HEATS

The specific heats at constant pressure and constant volume are defined by

$$c_{p} \equiv \left(\frac{\partial q}{\partial T}\right)_{p} = \left(\frac{\partial h}{\partial T}\right)_{p} \tag{11}$$

$$c_{v} \equiv \left(\frac{\partial q}{\partial T}\right)_{v} = \left(\frac{\partial u}{\partial T}\right)_{v} \tag{12}$$

It can be shown that

$$c_{p} - c_{v} = \left[ \left( \frac{\partial u}{\partial v} \right)_{T} + p \right] \left( \frac{\partial v}{\partial T} \right)_{p} = -T \frac{\left( \frac{\partial p}{\partial T} \right)_{v}^{2}}{\left( \frac{\partial p}{\partial v} \right)_{x}}$$
(13a)

$$c_{p} - c_{v} = R$$
 [therm perf] (13b)

The ratio of specific heats is defined as

$$\gamma \equiv \frac{c_p}{c_n} \tag{14}$$

According to the kinetic theory of gases, for many gases over a moderate range of temperature,

$$\gamma = \frac{n+2}{n} \tag{15}$$

where n is the number of effective degrees of freedom of the gas molecule. Useful relations for thermally perfect gases are

$$c_{\nu} = \frac{dh}{dT} = c_{\nu} + R = \frac{\gamma R}{\gamma - 1}$$
 [therm perf] (16)

$$c_v = \frac{du}{dT} = c_p - R = \frac{R}{\gamma - 1}$$
 [therm perf] (17)

#### ENTHALPY

The enthalpy of a gas is defined by

$$h \equiv u + pv \tag{18}$$

It follows that

$$dh = du + p \ dv + v \ dp = dq + v \ dp$$

$$= \left[c_v + v\left(\frac{\partial p}{\partial T}\right)_v\right] dT + \left[v\left(\frac{\partial p}{\partial v}\right)_T + T\left(\frac{\partial p}{\partial T}\right)_v\right] dv \quad (19a)$$

$$dh = (c_v + R)dT = c_v dT$$
 [therm perf] (19b)

$$h = (c_v + R)T + u_\tau = c_p T + u_\tau \quad [perf] \tag{20}$$

#### ENTROPY

The entropy is defined by

$$ds = \left(\frac{dq}{T}\right)_{rev} \tag{21}$$

It follows that

$$ds = \left(\frac{du + dw}{T}\right)_{rev} = \left(\frac{du + p dv}{T}\right)_{rev} = c_v \frac{dT}{T} + \left(\frac{\partial p}{\partial T}\right)_v dv \qquad (22a)$$

$$ds = c_{v} \frac{dT}{T} + R \frac{dv}{v}$$

$$= c_{v} \frac{dT}{T} - R \frac{d\rho}{\rho}$$

$$= c_{v} \frac{dT}{T} - R \frac{d\rho}{p}$$

$$= c_{v} \frac{dp}{p} - c_{v} \frac{d\rho}{\rho}$$
(22b)

$$s - s_r = c_v \ln \frac{T}{T_r} - R \ln \frac{\rho}{\rho_r}$$

$$= c_v \ln \frac{T}{T_r} - R \ln \frac{p}{p_r}$$

$$= c_v \ln \frac{p}{p_r} - c_v \ln \frac{\rho}{\rho_r}$$
[perf] (23a)

$$s - s_r = c_v \ln \frac{T/T_r}{(\rho/\rho_r)^{\gamma - 1}}$$

$$= c_p \ln \frac{T/T_r}{(\rho/\rho_r)^{(\gamma - 1)/\gamma}}$$

$$= c_v \ln \frac{\rho/p_r}{(\rho/\rho_r)^{\gamma}}$$
[perf] (23b)

$$\frac{p}{\rho^{\gamma}} = \frac{p_r}{\rho_r^{\gamma}} e^{(s-s_r)/c_v} \quad [perf] \tag{24}$$

The second law of thermodynamics requires that

$$s - s_{\tau} \ge 0 \quad [adiab] \tag{25}$$

#### CONTINUOUS ONE-DIMENSIONAL FLOW

#### BASIC EQUATIONS AND DEFINITIONS

The basic equations for the continuous flow of an inviscid non-heat-conducting gas along a streamline are as follows: Thermal equation of state

$$\frac{p}{q} = RT$$
 [therm perf] (26)

Dynamic equation

$$\frac{1}{\rho} dp + V dV = 0 \tag{27}$$

Energy equation

$$\frac{du + d\left(\frac{p}{\rho}\right) + VdV = 0}{dh + VdV = 0}$$
 [abiab] (28a)

$$\frac{c_{p} dT + V dV = 0}{\frac{\gamma}{\gamma - 1} d\left(\frac{p}{\rho}\right) + V dV = 0}$$
 [adiab, therm perf] (28b)

Additional useful variables are defined as follows: Speed of sound

$$a = \sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s} = \sqrt{\gamma \left(\frac{\partial p}{\partial \rho}\right)_T}$$
 (29a)

$$= \sqrt{\gamma \frac{p}{\rho}} = \sqrt{\gamma RT} \quad \text{[therm perf]} \tag{29b}$$

 $\cong$  49.0  $\sqrt{T}$  ft/sec for air if T is in degrees Rankine (=degrees Fahrenheit+459.6) (29c)

Mach number

$$M \equiv \frac{V}{a} \tag{30}$$

Dynamic pressure

$$q = \frac{1}{2} \rho V^2 \tag{31a}$$

$$= \frac{\gamma}{2} p M^2 \quad [\text{therm perf}] \tag{31b}$$

#### INTEGRATED FORMS OF ENERGY EQUATION

The energy equation (28) can be integrated at once to obtain

$$h + \frac{V^2}{2} = \text{constant} = h_t \quad [\text{adiab}]$$
 (32a)

$$c_{p}T + \frac{V^{2}}{2} = c_{p}T_{t}$$

$$\frac{\gamma}{\gamma - 1} \left(\frac{p}{\rho}\right) + \frac{V^{2}}{2} = \frac{\gamma}{\gamma - 1} \left(\frac{p_{t}}{\rho_{t}}\right)$$

$$\frac{a^{2}}{\gamma - 1} + \frac{V^{2}}{2} = \frac{a_{t}^{2}}{\gamma - 1}$$

$$\frac{a^{2}}{\gamma - 1} + \frac{V^{2}}{2} = \frac{1}{2} \left(\frac{\gamma + 1}{\gamma - 1}\right) a_{*}^{2}$$

$$\frac{a^{2}}{\gamma - 1} + \frac{V^{2}}{2} = \frac{V_{m}^{2}}{2}$$
[adiab, perf] (32b)

The three reference speeds  $a_t$ ,  $a_*$ , and  $V_m$  are related by

$$\left(\frac{a_t}{a_*}\right)^2 = \frac{\gamma+1}{2}$$

$$\left(\frac{V_m}{a_*}\right)^2 = \frac{\gamma+1}{\gamma-1}$$
[adiab, perf]
$$\left(\frac{V_m}{a_t}\right)^2 = \frac{2}{\gamma-1}$$
(33)

#### PRESSURE-DENSITY RELATION

From equations (27) and (28b) it follows that

$$\frac{p}{\rho^{\gamma}} = \text{constant} = \frac{p_t}{\rho_t^{\gamma}}$$
 [isen, perf] (34)

from which

$$\frac{p}{p_t} = \left(\frac{\rho}{\rho_t}\right)^{\gamma} = \left(\frac{T}{T_t}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{a}{a_t}\right)^{\frac{2\gamma}{\gamma-1}} \quad \text{[isen, perf]}$$
 (35)

#### BERNOULLI'S EQUATION

Combination of equations (32b) and (35) gives Bernoulli's equation for compressible flow in the form

$$\frac{\gamma}{\gamma - 1} \left( \frac{p_t}{\rho_t} \right) \left( \frac{p}{p_t} \right)^{\frac{\gamma - 1}{\gamma}} + \frac{V^2}{2} = \frac{\gamma}{\gamma - 1} \left( \frac{p_t}{\rho_t} \right) \quad [\text{isen, perf}] \quad (36)$$

#### RELATIONS BETWEEN LOCAL AND FREE-STREAM CONDITIONS

With the aid of the foregoing equations it can be shown that

$$\frac{T}{T_{\infty}} = 1 - \frac{\gamma - 1}{2} M_{\infty}^{2} \left[ \left( \frac{V}{V_{\infty}} \right)^{2} - 1 \right] \qquad \text{[adiab, perf]} \quad (37)$$

$$\frac{p}{p_{\infty}} = \left\{ 1 - \frac{\gamma - 1}{2} M_{\infty}^{2} \left[ \left( \frac{V}{V_{\infty}} \right)^{2} - 1 \right] \right\}^{\frac{\gamma}{\gamma - 1}} \quad \text{[isen, perf]} \quad (38)$$

$$\frac{\rho}{\rho_{\infty}} = \left\{ 1 - \frac{\gamma - 1}{2} M_{\infty}^{2} \left[ \left( \frac{V}{V_{\infty}} \right)^{2} - 1 \right] \right\}^{\frac{1}{\gamma - 1}} \quad \text{[isen perf]} \quad (39)$$

In small-disturbance theory, where it is assumed that  $(V-V_{\infty})\ll V_{\infty}$ , these equations take on the simplified form

$$\frac{T}{T_{\infty}} \cong 1 - (\gamma - 1) M_{\infty}^{2} \frac{V - V_{\infty}}{V_{\infty}} \quad [adiab, perf]$$
 (40)

$$\frac{p}{p_{m}} \cong 1 - \gamma M_{\infty}^{2} \frac{V - V_{\infty}}{V_{m}} \quad \text{[isen, perf]}$$
 (41)

$$\frac{\rho}{\rho_{\infty}} \cong 1 - M_{\infty}^2 \frac{V - V_{\infty}}{V_{\infty}} \quad [\text{isen, perf}]$$
 (42)

#### USEFUL RATIOS

On the basis of the above results, useful relations can be derived expressing various dimensionless ratios as functions of a single parameter. These relations are given below, grouped according to which of the various parameters  $(M, V/a_*, V/a_t, \text{ or } V/V_m)$  is used as the independent variable.

In each case the second form of the equation applies for  $\gamma = \frac{7}{5}$ .

Parameter M.—

$$\frac{T}{T_{t}} = \left(1 + \frac{\gamma - 1}{2} M^{2}\right)^{-1} = \left(1 + \frac{M^{2}}{5}\right)^{-1} \text{ [adiab, perf]} (43)$$

$$\frac{p}{p_t} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma}{\gamma - 1}} = \left(1 + \frac{M^2}{5}\right)^{-\frac{7}{2}} \text{ [isen, perf] (44)}$$

$$\frac{\rho}{\rho_t} = \left(1 + \frac{\gamma - 1}{2}M^2\right)^{-\frac{1}{\gamma - 1}} = \left(1 + \frac{M^2}{5}\right)^{-\frac{5}{2}} \text{ [isen, perf] (45)}$$

$$\frac{a}{a_t} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{1}{2}} = \left(1 + \frac{M^2}{5}\right)^{-\frac{1}{2}} \text{ [adiab, perf] (46)}$$

EQUATIONS, TABLES, AND CHARMALES, 
$$\frac{q}{p} = \frac{\gamma}{2} M^2 = \frac{7}{10} M^2$$
 [therm perf] (47)
$$\frac{q}{p_t} = \frac{\gamma}{2} M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma}{\gamma - 1}}$$

$$= \frac{7}{10} M^2 \left(1 + \frac{M^2}{5}\right)^{-\frac{\gamma}{2}}$$
 [isen, perf] (48)
$$\left(\frac{V}{a_t}\right)^2 = M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-1}$$

$$= M^2 \left(1 + \frac{M^2}{5}\right)^{-1}$$
 [adiab, perf] (49)
$$\left(\frac{V}{a_*}\right)^2 = \frac{\gamma + 1}{2} M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-1}$$

$$= \frac{6M^2}{5} \left(1 + \frac{M^2}{5}\right)^{-1}$$
 [adiab, perf] (50)
$$\left(\frac{V}{V_m}\right)^2 = \frac{\gamma - 1}{2} M^2 \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-1}$$

$$= \frac{M^2}{5} \left(1 + \frac{M^2}{5}\right)^{-1}$$
 [adiab, perf] (51)
$$\mathbf{Parameter} \frac{V}{a_*}...$$

$$\frac{T}{T_t} = 1 - \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_*}\right)^2 = 1 - \frac{1}{6} \left(\frac{V}{a_*}\right)^2$$
 [adiab, perf] (52)
$$\frac{p}{p_t} = \left[1 - \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_*}\right)^2\right]^{\frac{\gamma}{\gamma - 1}}$$

$$= \left[1 - \frac{1}{6} \left(\frac{V}{a_*}\right)^2\right]^{\frac{\gamma}{2}}$$
 [isen, perf] (53)

$$\begin{split} \frac{p}{p_{t}} = & \left[ 1 - \frac{\gamma - 1}{\gamma + 1} \left( \frac{V}{a_{*}} \right)^{2} \right]^{\frac{\gamma}{\gamma - 1}} \\ = & \left[ 1 - \frac{1}{6} \left( \frac{V}{a_{*}} \right)^{2} \right]^{\frac{7}{2}} \quad \text{[isen, perf]} \quad (53) \\ \frac{\rho}{\rho_{t}} = & \left[ 1 - \frac{\gamma - 1}{\gamma + 1} \left( \frac{V}{a_{*}} \right)^{2} \right]^{\frac{1}{\gamma - 1}} \\ = & \left[ 1 - \frac{1}{6} \left( \frac{V}{a_{*}} \right)^{2} \right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (54) \end{split}$$

$$\frac{a}{a_{t}} = \left[1 - \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_{*}}\right)^{2}\right]^{\frac{1}{2}}$$

$$= \left[1 - \frac{1}{6} \left(\frac{V}{a_{*}}\right)^{2}\right]^{\frac{1}{2}} \quad \text{[adiab, perf]} \quad (55)$$

$$\frac{q}{p} = \frac{\gamma}{\gamma + 1} \left(\frac{V}{a_{*}}\right)^{2} \left[1 - \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_{*}}\right)^{2}\right]^{-1}$$

$$= \frac{7}{12} \left(\frac{V}{a_{*}}\right)^{2} \left[1 - \frac{1}{6} \left(\frac{V}{a_{*}}\right)^{2}\right]^{-1} \quad \text{[adiab, perf]} \quad (56)$$

$$\frac{q}{p_t} = \frac{\gamma}{\gamma + 1} \left(\frac{V}{a_*}\right)^2 \left[1 - \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_*}\right)^2\right]^{\frac{1}{\gamma - 1}}$$

$$= \frac{7}{12} \left(\frac{V}{a_*}\right)^2 \left[1 - \frac{1}{6} \left(\frac{V}{a_*}\right)^2\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (57)$$

$$\begin{split} M^2 &= \frac{2}{\gamma + 1} \left( \frac{V}{a_*} \right)^2 \left[ 1 - \frac{\gamma - 1}{\gamma + 1} \left( \frac{V}{a_*} \right)^2 \right]^{-1} \\ &= \frac{5}{6} \left( \frac{V}{a_*} \right)^2 \left[ 1 - \frac{1}{6} \left( \frac{V}{a_*} \right)^2 \right]^{-1} \quad [\text{adiab, perf}] \quad (58) \end{split}$$

$$\left(\frac{V}{a_t}\right)^2 = \frac{2}{\gamma + 1} \left(\frac{V}{a_*}\right)^2 = \frac{5}{6} \left(\frac{V}{a_*}\right)^2 \quad [adiab, perf] \tag{59}$$

$$\left(\frac{V}{V_{m}}\right)^{2} = \frac{\gamma - 1}{\gamma + 1} \left(\frac{V}{a_{*}}\right)^{2} = \frac{1}{6} \left(\frac{V}{a_{*}}\right)^{2} \quad [\text{adiab, perf}] \tag{60}$$

Parameter  $\frac{V}{a}$ .—

$$\frac{T}{T_t} = 1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2 = 1 - \frac{1}{5} \left(\frac{V}{a_t}\right)^2$$
 [adiab, perf] (61)

$$\frac{p}{p_t} = \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2\right]^{\frac{\gamma}{\gamma - 1}}$$

$$= \left[1 - \frac{1}{5} \left(\frac{V}{a_t}\right)^2\right]^{\frac{\gamma}{2}} \quad \text{[isen, perf]} \quad (62)$$

$$\frac{\rho}{\rho_t} = \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2\right]^{\frac{1}{\gamma - 1}}$$

$$= \left[1 - \frac{1}{5} \left(\frac{V}{a_t}\right)^2\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (63)$$

$$\frac{a}{a_{t}} = \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_{t}}\right)^{2}\right]^{\frac{1}{2}}$$

$$= \left[1 - \frac{1}{5} \left(\frac{V}{a_{t}}\right)^{2}\right]^{\frac{1}{2}} \quad [adiab, perf] \quad (64)$$

$$\frac{q}{p} = \frac{\gamma}{2} \left(\frac{V}{a_t}\right)^2 \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2\right]^{-1}$$

$$= \frac{7}{10} \left(\frac{V}{a_t}\right)^2 \left[1 - \frac{1}{5} \left(\frac{V}{a_t}\right)^2\right]^{-1} \quad [adiab, perf] \quad (65)$$

$$\frac{q}{p_t} = \frac{\gamma}{2} \left(\frac{V}{a_t}\right)^2 \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2\right]^{\frac{1}{\gamma - 1}}$$

$$= \frac{7}{10} \left(\frac{V}{a_t}\right)^2 \left[1 - \frac{1}{5} \left(\frac{V}{a_t}\right)^2\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (66)$$

$$M^{2} = \left(\frac{V}{a_{t}}\right)^{2} \left[1 - \frac{\gamma - 1}{2} \left(\frac{V}{a_{t}}\right)^{2}\right]^{-1}$$

$$= \left(\frac{V}{a_{t}}\right)^{2} \left[1 - \frac{1}{5} \left(\frac{V}{a_{t}}\right)^{2}\right]^{-1} \quad [adiab, perf] \quad (67)$$

$$\left(\frac{V}{a_*}\right)^2 = \frac{\gamma + 1}{2} \left(\frac{V}{a_t}\right)^2 = \frac{6}{5} \left(\frac{V}{a_t}\right)^2 \quad [adiab, perf] \tag{68}$$

$$\left(\frac{V}{V_m}\right)^2 = \frac{\gamma - 1}{2} \left(\frac{V}{a_t}\right)^2 = \frac{1}{5} \left(\frac{V}{a_t}\right)^2 \quad [adiab, perf] \tag{69}$$

Parameter  $\frac{V}{V_m}$ .

$$\frac{T}{T_t} = 1 - \left(\frac{V}{V_m}\right)^2 \quad [\text{adiab, perf}] \tag{70}$$

$$\frac{p}{p_t} = \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{\gamma}{\gamma - 1}} = \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{7}{2}} \quad \text{[isen, perf]} \quad (71)$$

$$\frac{\rho}{\rho_t} = \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{1}{\gamma - 1}} = \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (72)$$

$$\frac{a}{a_t} = \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{1}{2}} \quad \text{[adiab, perf]} \tag{73}$$

$$\frac{q}{p} = \frac{\gamma}{\gamma - 1} \left(\frac{V}{V_m}\right)^2 \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{-1}$$

$$= \frac{7}{2} \left(\frac{V}{V_m}\right)^2 \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{-1} \quad [adiab, perf] \quad (74)$$

$$\frac{q}{p_t} = \frac{\gamma}{\gamma - 1} \left(\frac{V}{V_m}\right)^2 \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{1}{\gamma - 1}}$$

$$= \frac{7}{2} \left(\frac{V}{V_m}\right)^2 \left[1 - \left(\frac{V}{V_m}\right)^2\right]^{\frac{5}{2}} \qquad \text{[isen, perf]} \quad (75)$$

$$M^{2} = \frac{2}{\gamma + 1} \left(\frac{V}{V_{m}}\right)^{2} \left[1 - \left(\frac{V}{V_{m}}\right)^{2}\right]^{-1}$$

$$= \frac{5}{6} \left(\frac{V}{V_{m}}\right)^{2} \left[1 - \left(\frac{V}{V_{m}}\right)^{2}\right]^{-1} \quad [adiab, perf] \quad (76)$$

$$\left(\frac{V}{a_t}\right)^2 = \frac{2}{\gamma - 1} \left(\frac{V}{V_m}\right)^2 = 5 \left(\frac{V}{V_m}\right)^2 \quad [adiab, perf]$$
 (77)

$$\left(\frac{V}{a_*}\right)^2 = \frac{\gamma + 1}{\gamma - 1} \left(\frac{V}{V_m}\right)^2 = 6 \left(\frac{V}{V_m}\right)^2 \quad [adiab, perf]$$
 (78)

Tables I and II list numerical values of the following ratios with Mach number M as the independent variable:

$$\frac{p}{p_t}, \frac{\rho}{\rho_t}, \frac{T}{T_t}, \frac{q}{p_t}, \frac{V}{a_*}$$

#### STREAM-TUBE-AREA RELATIONS

If it is assumed that the density and speed are uniform across any section of a given stream tube, then the equation of continuity is

$$\rho VA = \text{constant} = \rho_* a_* A_* \tag{79}$$

By combining this and certain of the foregoing equations, the area ratio  $A_{\star}/A$  can be expressed as a function of any one of the four parameters used above. The final equations are

$$\begin{split} \frac{A_*}{A} &= \left(\frac{\gamma + 1}{2}\right)^{\frac{\gamma + 1}{2(\gamma - 1)}} M \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma + 1}{2(\gamma - 1)}} \\ &= \frac{216}{125} M \left(1 + \frac{M^2}{5}\right)^{-3} \quad \text{[isen, perf]} \quad (80) \end{split}$$

$$\frac{A_{*}}{A} = \left(\frac{\gamma+1}{2}\right)^{\frac{1}{\gamma-1}} \left(\frac{V}{a_{*}}\right) \left[1 - \frac{\gamma-1}{\gamma+1} \left(\frac{V}{a_{*}}\right)^{2}\right]^{\frac{1}{\gamma-1}} \\
= \left(\frac{6}{5}\right)^{\frac{5}{2}} \left(\frac{V}{a_{*}}\right) \left[1 - \frac{1}{6} \left(\frac{V}{a_{*}}\right)^{2}\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (81)$$

$$\frac{A_{*}}{A} = \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \left(\frac{V}{a_{t}}\right) \left[1 - \frac{\gamma-1}{2} \left(\frac{V}{a_{t}}\right)^{2}\right]^{\frac{1}{\gamma-1}} \\
= \frac{216}{125} \left(\frac{V}{a_{t}}\right) \left[1 - \frac{1}{5} \left(\frac{V}{a_{t}}\right)^{2}\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (82)$$

$$\frac{A_{*}}{A} = \left(\frac{2}{\gamma-1}\right)^{\frac{1}{2}} \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \left(\frac{V}{V_{m}}\right) \left[1 - \left(\frac{V}{V_{m}}\right)^{2}\right]^{\frac{1}{\gamma-1}} \\
= 5^{\frac{1}{2}} \left(\frac{216}{125}\right) \left(\frac{V}{V_{m}}\right) \left[1 - \left(\frac{V}{V_{m}}\right)^{2}\right]^{\frac{5}{2}} \quad \text{[isen, perf]} \quad (83)$$

Numerical values of  $A_*/A$  as a function of M are given in tables I and II.

Equation (79) combined with equations (26), (29b), (45), and (46) can be employed to obtain the mass-flow rate per unit area  $\rho V$  along a stream tube as a function of Mach number, total temperature, and total pressure. Numerical values can be obtained conveniently from chart 1 where the variation with Mach number of the mass-flow rate per unit cross-sectional area is presented for various total temperatures and a total pressure of 1 pound per square inch absolute.

#### SHOCK WAVES

#### NORMAL SHOCK WAVES

#### BASIC EQUATIONS

The previous relations for isentropic flow are valid on either side of a shock wave, but not across it, because at the shock wave the flow quantities have discontinuities. Jump

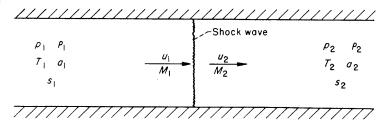


FIGURE 1.—Notation for normal shock wave.

conditions for a steady normal shock wave (fig. 1) result from requiring conservation of

mass: 
$$\rho_1 u_1 = \rho_2 u_2 \tag{84}$$

momentum: 
$$p_1 + \rho_1 u_1^2 = p_2 + \rho_2 u_2^2$$
 (85)

energy:<sup>3</sup> 
$$\frac{1}{2}u_1^2 + h_1 = \frac{1}{2}u_2^2 + h_2$$
 [adiab] (86a)

<sup>&</sup>lt;sup>3</sup> The actual relation for conservation of energy is  $\rho_1 u_1 \left(\frac{1}{2} u_1^2 + h_1\right) = \rho_2 u_2 \left(\frac{1}{2} u_2^2 + h_2\right)$ ; it reduces to the above form in view of equation (84).

$$\frac{1}{2} u_1^2 + c_p T_1 = \frac{1}{2} u_2^2 + c_p T_2$$

$$\frac{1}{2} u_1^2 + \frac{\gamma}{\gamma - 1} \frac{p_1}{\rho_1} = \frac{1}{2} u_2^2 + \frac{\gamma}{\gamma - 1} \frac{p_2}{\rho_2}$$

$$\frac{1}{2} u_1^2 + \frac{1}{\gamma - 1} a_1^2 = \frac{1}{2} u_2^2 + \frac{1}{\gamma - 1} a_2^2$$
[adiab, perf] (86b)

together with the requirement that the entropy does not decrease:

$$\Delta s \equiv s_2 - s_1 \ge 0 \tag{87}$$

It follows immediately from the energy relation (86) that total enthalpy, total temperature, and total speed of sound are constant across the shock and hence (from the previous relations (33) for adiabatic flow) also the critical speed of sound and limiting speed:

$$h_{t_1} = h_{t_2} \quad [adiab] \tag{88a}$$

$$\left. \begin{array}{l}
 T_{t_1} = T_{t_2} \\
 a_{t_1} = a_{t_2} \\
 a_{*_1} = a_{*_2} \\
 V_{m_2} = V_{m_2}
 \end{array} \right\} \quad [adiab, perf] \tag{88b}$$

Combining equations (84) to (86) leads to Prandtl's relation

$$u_1 u_2 = a_*^2 = \frac{p_2 - p_1}{\rho_2 - \rho_1}$$
 [adiab, perf] (89)

which implies that the flow is supersonic ahead of the shock wave and subsonic behind (the reverse possibility is ruled out by the requirement of nondecreasing entropy), and to the Rankine-Hugoniot relations

$$\frac{p_2}{p_1} = \frac{(\gamma + 1) \ \rho_2 - (\gamma - 1) \ \rho_1}{(\gamma + 1) \ \rho_1 - (\gamma - 1) \ \rho_2} \quad [adiab, perf]$$
(90)

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma + 1) \ p_2 + (\gamma - 1) \ p_1}{(\gamma + 1) \ p_1 + (\gamma - 1) \ p_2} \quad [adiab, perf]$$
(91)

$$\frac{p_2 - p_1}{\rho_2 - \rho_1} = \gamma \frac{p_2 + p_1}{\rho_2 + \rho_1} \quad [adiab, perf]$$
 (92)

#### USEFUL RELATIONS

Many relations for normal shock waves are conveniently expressed in terms of either upstream Mach number  $M_1$  or the static-pressure ratio across the shock  $\xi \equiv p_2/p_1$ . The following relations apply to adiabatic flow of a completely perfect fluid. The last form of each equation holds for  $\gamma = 7/5$ .

Parameter  $M_1$ .—

$$\frac{p_2}{p_1} = \xi = \frac{2\gamma M_1^2 - (\gamma - 1)}{\gamma + 1} = \frac{7M_1^2 - 1}{6}$$
(93)

$$\frac{\rho_2}{\rho_1} = \frac{u_1}{u_2} = \frac{u_1^2}{a_*^2} = \frac{a_*^2}{u_2^2} = \frac{(\gamma + 1) M_1^2}{(\gamma - 1) M_1^2 + 2} = \frac{6M_1^2}{M_1^2 + 5}$$
(94)

$$\frac{T_{2}}{T_{1}} = \frac{a_{2}^{2}}{a_{1}^{2}} = \frac{[2\gamma M_{1}^{2} - (\gamma - 1)] [(\gamma - 1) M_{1}^{2} + 2]}{(\gamma + 1)^{2} M_{1}^{2}} \\
= \frac{(7M_{1}^{2} - 1) (M_{1}^{2} + 5)}{36M_{2}^{2}} \quad (95)$$

$$M_2^2 = \frac{(\gamma - 1) M_1^2 + 2}{2\gamma M_1^2 - (\gamma - 1)} = \frac{M_1^2 + 5}{7 M_1^2 - 1}$$
(96)

$$\frac{p_{2}}{p_{t_{1}}} = \frac{2\gamma M_{1}^{2} - (\gamma - 1)}{\gamma + 1} \left[ \frac{2}{(\gamma - 1) M_{1}^{2} + 2} \right]^{\frac{\gamma}{\gamma - 1}} \\
= \frac{7M_{1}^{2} - 1}{6} \left( \frac{5}{M_{1}^{2} + 5} \right)^{\frac{7}{2}} . (97)$$

$$\frac{p_2}{p_{t_2}} = \left[ \frac{4\gamma M_1^2 - 2(\gamma - 1)}{(\gamma + 1)^2 M_1^2} \right]^{\frac{\gamma}{\gamma - 1}} = \left[ \frac{5(7M_1^2 - 1)}{36M_1^2} \right]^{\frac{7}{2}}$$
(98)

$$\frac{p_{t_2}}{p_{t_1}} = \frac{\rho_{t_2}}{\rho_{t_1}} = e^{-\frac{\Delta s}{R}}$$

$$= \left[ \frac{(\gamma + 1) M_1^2}{(\gamma - 1) M_1^2 + 2} \right]^{\frac{\gamma}{\gamma - 1}} \left[ \frac{\gamma + 1}{2\gamma M_1^2 - (\gamma - 1)} \right]^{\frac{1}{\gamma - 1}}$$

$$= \left( \frac{6M_1^2}{M_2^2 + 5} \right)^{\frac{7}{2}} \left( \frac{6}{7M_2^2 - 1} \right)^{\frac{5}{2}} \tag{99}$$

$$\frac{p_{t_2}}{p_1} = \left[ \frac{(\gamma + 1) M_1^2}{2} \right]^{\frac{\gamma}{\gamma - 1}} \left[ \frac{\gamma + 1}{2\gamma M_1^2 - (\gamma - 1)} \right]^{\frac{1}{\gamma - 1}} \\
= \left( \frac{6M_1^2}{5} \right)^{\frac{7}{2}} \left( \frac{6}{7M_1^2 - 1} \right)^{\frac{5}{2}} (100)$$

(Rayleigh pitot formula)

$$\begin{split} \frac{\Delta s}{c_v} &= (\gamma - 1) \frac{\Delta s}{R} = -(\gamma - 1) \ln \left( \frac{p_{t_2}}{p_{t_1}} \right) \\ &= \ln \left[ \frac{2\gamma M_1^2 - (\gamma - 1)}{\gamma + 1} \right] - \gamma \ln \left[ \frac{(\gamma + 1)M_1^2}{(\gamma - 1)M_1^2 + 2} \right] \\ &= \ln \left( \frac{7M_1^2 - 1}{6} \right) - \frac{7}{5} \ln \left( \frac{6M_1^2}{M_1^2 + 5} \right) \end{split}$$
(101)

$$\frac{p_2 - p_1}{q_1} = \frac{4(M_1^2 - 1)}{(\gamma + 1)M_1^2} = \frac{5(M_1^2 - 1)}{3M_1^2}$$
 (102)

Numerical values from equations (93), (94), (95), (96), (99), and (100) (with  $\gamma = 7/5$ ) are given in table II.

For weak shock waves ( $M_1$  only slightly greater than unity) the following series are useful:

$$\frac{p_{t_2}}{p_{t_1}} = 1 - \frac{2\gamma}{3(\gamma+1)^2} (M_1^2 - 1)^3 + \frac{2\gamma^2}{(\gamma+1)^3} (M_1^2 - 1)^4 + \cdots$$

$$= 1 - \frac{35}{216} (M_1^2 - 1)^3 + \frac{245}{864} (M_1^2 - 1)^4 + \cdots$$
(103)

$$\frac{\Delta s}{R} = \frac{1}{\gamma - 1} \frac{\Delta s}{c_v} = \frac{2\gamma}{3(\gamma + 1)^2} (M_1^2 - 1)^3 - \frac{2\gamma^2}{(\gamma + 1)^3} (M_1^2 - 1)^4 + \cdots$$

$$=\frac{35}{216}(M_1^2-1)^3-\frac{245}{864}(M_1^2-1)^4+\cdots \qquad (104)$$

Parameter  $\xi \equiv p_2/p_1$ .—

$$M_1^2 = \frac{(\gamma+1)\xi + (\gamma-1)}{2\gamma} = \frac{6\xi+1}{7}$$
 (105)

$$\frac{\rho_2}{\rho_1} = \frac{u_1}{u_2} = \frac{(\gamma+1)\xi + (\gamma-1)}{(\gamma-1)\xi + (\gamma+1)} = \frac{6\xi + 1}{\xi + 6}$$
 (106)

$$\frac{T_2}{T_1} = \frac{a_2^2}{a_1^2} = \xi \frac{(\gamma - 1)\xi + (\gamma + 1)}{(\gamma + 1)\xi + (\gamma - 1)} = \xi \frac{\xi + 6}{6\xi + 1}$$
(107)

$$M_2^2 = \frac{(\gamma - 1)\xi + (\gamma + 1)}{2\gamma\xi} = \frac{\xi + 6}{7\xi}$$
 (108)

$$\frac{p_2}{p_{i_1}} = \xi \frac{p_1}{p_{i_1}} = \xi \left\{ \frac{4\gamma}{(\gamma+1)[(\gamma-1)\xi+(\gamma+1)]} \right\}^{\frac{\gamma}{\gamma-1}} = \xi \left[ \frac{35}{6(\xi+6)} \right]^{\frac{7}{2}}$$
(109)

$$\frac{p_2}{p_{t_2}} = \xi \frac{p_1}{p_{t_2}} = \left\{ \frac{4\gamma\xi}{(\gamma+1)[(\gamma+1)\xi+(\gamma-1)]} \right\}^{\frac{\gamma}{\gamma-1}} = \left[ \frac{35\xi}{6(6\xi+1)} \right]^{\frac{7}{2}}$$
(110)

$$\frac{p_{t_2}}{p_{t_1}} = \frac{\rho_{t_2}}{\rho_{t_1}} = e^{-\frac{\Delta s}{R}} = \xi^{-\frac{1}{\gamma - 1}} \left[ \frac{(\gamma + 1)\xi + (\gamma - 1)}{(\gamma - 1)\xi + (\gamma + 1)} \right]^{\frac{\gamma}{\gamma - 1}}$$

$$= \left(\frac{1}{\xi}\right)^{\frac{5}{2}} \left(\frac{6\xi+1}{\xi+6}\right)^{\frac{7}{2}} \tag{111}$$

$$\frac{\Delta s}{c_{v}} = (\gamma - 1) \frac{\Delta s}{R} = -(\gamma - 1) \ln \left( \frac{p_{t_2}}{p_{t_1}} \right) = \ln \xi -$$

$$\gamma \ln \left[ \frac{(\gamma+1)\xi + (\gamma-1)}{(\gamma-1)\xi + (\gamma+1)} \right] = \ln \xi - \frac{7}{5} \ln \left( \frac{6\xi+1}{\xi+6} \right) \quad (112)$$

For weak shock waves ( $\xi$  only slightly greater than unity)

$$\frac{p_{t_2}}{p_{t_1}} = 1 - \frac{\gamma + 1}{12\gamma^2} (\xi - 1)^3 + \frac{\gamma + 1}{8\gamma^2} (\xi - 1)^4 + \cdots 
= 1 - \frac{5}{40} (\xi - 1)^3 + \frac{15}{08} (\xi - 1)^4 + \cdots$$
(113)

$$\frac{\Delta s}{R} = \frac{1}{\gamma - 1} \frac{\Delta s}{c_v} = \frac{\gamma + 1}{12\gamma^2} (\xi - 1)^3 - \frac{\gamma + 1}{8\gamma^2} (\xi - 1)^4 + \cdots$$

$$=\frac{5}{49}(\xi-1)^3 - \frac{15}{98}(\xi-1)^4 + \cdots$$
 (114)

In unsteady flow a normal shock wave acts at each instant as a steady shock. Hence all the above relations are valid across a moving normal shock wave if instantaneous velocities are measured relative to the shock.

#### OBLIQUE SHOCK WAVES

In general, a three-dimensional shock wave will be curved, and will separate two regions of nonuniform flow. However, the shock transition at each point takes place instantaneously, so that it is sufficient to consider an arbitrarily small neighborhood of the point. In such a neighborhood

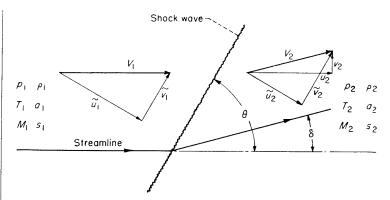


FIGURE 2.—Notation for oblique shock wave.

the shock wave may be regarded as plane to any desired degree of accuracy, and the flows on either side as uniform and parallel. Moreover, with the proper orientation of axes the flow is locally two-dimensional. Hence it is sufficient to consider a straight oblique shock wave in a uniform parallel two-dimensional stream, as shown in figure 2.

#### BASIC EQUATIONS

For a steady oblique shock wave, jump conditions result from requiring conservation of

mass: 
$$\rho_1 \tilde{u}_1 = \rho_2 \tilde{u}_2 \tag{115}$$

normal momentum: 
$$p_1 + \rho_1 \tilde{u}_1^2 = p_2 + \rho_2 \tilde{u}_2^2$$
 (116)

tangential momentum: 
$$\rho_1 \tilde{u}_1 \tilde{v}_1 = \rho_2 \tilde{u}_2 \tilde{v}_2$$
 (117)

energy<sup>4</sup>: 
$$\frac{1}{2} (\tilde{u}_1^2 + \tilde{v}_1^2) + h_1 = \frac{1}{2} (\tilde{u}_2^2 + \tilde{v}_2^2) + h_2 [\text{adiab}]$$
 (118a)

$$\frac{1}{2} \underbrace{(\tilde{u}_{1}^{2} + \tilde{v}_{1}^{2}) + c_{p} T_{1} = \frac{1}{2} (\tilde{u}_{2}^{2} + \tilde{v}_{2}^{2}) + c_{p} T_{2}}_{1} + \frac{1}{2} \underbrace{(\tilde{u}_{1}^{2} + \tilde{v}_{1}^{2}) + \frac{\gamma}{\gamma - 1} \frac{p_{1}}{\rho_{1}}}_{\rho_{1}} = \frac{1}{2} \underbrace{(\tilde{u}_{2}^{2} + \tilde{v}_{2}^{2}) + \frac{\gamma}{\gamma - 1} \frac{p_{2}}{\rho_{2}}}_{\rho_{2}} \left[ \underbrace{\frac{1}{2} (\tilde{u}_{1}^{2} + \tilde{v}_{1}^{2}) + \frac{1}{\gamma - 1} a_{1}^{2}}_{1} = \frac{1}{2} \underbrace{(\tilde{u}_{2}^{2} + \tilde{v}_{2}^{2}) + \frac{1}{\gamma - 1} a_{2}^{2}}_{\rho_{2}} \right]$$
(118b)

together with the requirement that the entropy does not decrease:

$$\Delta s \equiv s_2 - s_1 \ge 0 \tag{119}$$

Again it follows from the energy relation (118) that total enthalpy, total temperature, and total speed of sound are constant across the shock and hence also the critical speed of sound and limiting speed:

$$h_{t_1} = h_{t_2} \quad [\text{adiab}] \tag{120}$$

$$\left\{
 \begin{array}{l}
 T_{t_1} = T_{t_2} \\
 a_{t_1} = a_{t_2} \\
 a_{*_1} = a_{*_2} \\
 V_{m_1} = V_{m_2}
 \end{array}
 \right\}
 \left[\begin{array}{l}
 \text{adiab,} \\
 \text{perf}
 \end{array}\right]$$
(121)

<sup>4</sup> Compare remark for normal shock waves, footnote on page 6.

#### CONNECTION WITH NORMAL SHOCK

A comparison of equation (115) with (117) shows that the tangential velocity is constant across the shock wave:

$$\tilde{v}_1 = \tilde{v}_2 \quad [adiab] \tag{122}$$

so that the change in velocity is normal to the shock. It follows that

$$\frac{1}{2} \tilde{v}_1^2 = \frac{1}{2} \tilde{v}_2^2$$

so that the energy equation (118a) reduces to

$$\frac{1}{2}\,\tilde{u}_{1}{}^{2}\!+\!h_{1}\!=\!\frac{1}{2}\,\tilde{u}_{2}{}^{2}\!+\!h_{2}\quad [\mathrm{adiab}] \tag{123}$$

Now equations (115), (116), and (123) involve only the component of velocity  $\tilde{u}$  normal to the shock, and are identical with equations (84), (85), and (86) for normal shock waves. Hence an oblique shock wave acts as a normal shock to the component of flow perpendicular to it, while the tangential component is unchanged. This is also clear physically from the "sweepback principle" that the oblique flow is reduced to the normal flow by a uniform translation of axes (Galilean transformation).

Because the speed of sound depends on the tangential velocity, Prandtl's relation differs from that for normal shock waves (see ref. 11, pp. 302–303):

$$\tilde{u}_1 \tilde{u}_2 = a_*^2 - \frac{\gamma - 1}{\gamma + 1} \tilde{v}^2$$
 [adiab, perf] (124)

where  $a_*$  and  $\tilde{v}$  can be evaluated on either side of the shock. The Rankine-Hugoniot relations are the same as for normal shock waves:

$$\frac{p_2}{p_1} = \frac{(\gamma+1)\rho_2 - (\gamma-1)\rho_1}{(\gamma+1)\rho_1 - (\gamma-1)\rho_2} \quad [adiab, perf]$$
 (125)

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)p_2 + (\gamma-1)p_1}{(\gamma+1)p_1 + (\gamma-1)p_2} \quad [adiab, perf]$$
 (126)

$$\frac{p_2 - p_1}{\rho_2 - \rho_1} = \gamma \frac{p_2 + p_1}{\rho_2 + \rho_1} \quad [adiab, perf]$$
 (127)

#### USEFUL RELATIONS

Because an oblique shock wave acts as a normal shock to the flow perpendicular to it, the previous relations for normal shocks (except those for ratios of static to total pressures) apply to oblique shocks if  $M_1$  and  $M_2$  are replaced by their normal components  $M_1$  sin  $\theta$  and  $M_2$  sin  $(\theta-\delta)$ . This gives most of the following relations; the remainder are derived from them by using the kinematic condition that the stream turns through an angle  $\delta$ , together with the previous isentropic-flow relations.

Parameters  $M_1$  and  $\theta$ .—

$$\frac{p_2}{p_1} = \xi = \frac{2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)}{\gamma + 1} = \frac{7M_1^2 \sin^2 \theta - 1}{6}$$
 (128)

$$\frac{\rho_2}{\rho_1} = \frac{\tilde{u}_1}{\tilde{u}_2} = \frac{(\gamma + 1)M_1^2 \sin^2 \theta}{(\gamma - 1)M_1^2 \sin^2 \theta + 2} = \frac{6M_1^2 \sin^2 \theta}{M_1^2 \sin^2 \theta + 5}$$
(129)

$$\begin{split} \frac{T_{2}}{T_{1}} &= \frac{a_{2}^{2}}{a_{1}^{2}} = \frac{[2\gamma M_{1}^{2} \sin^{2}\theta - (\gamma - 1)][(\gamma - 1)M_{1}^{2} \sin^{2}\theta + 2]}{(\gamma + 1)^{2}M_{1}^{2} \sin^{2}\theta} \\ &= \frac{(7M_{1}^{2} \sin^{2}\theta - 1)(M_{1}^{2} \sin^{2}\theta + 5)}{36M_{1}^{2} \sin^{2}\theta} \end{split} \tag{130}$$

$$M_{2}^{2}\sin^{2}(\theta-\delta) = \frac{(\gamma-1)M_{1}^{2}\sin^{2}\theta+2}{2\gamma M_{1}^{2}\sin^{2}\theta-(\gamma-1)} = \frac{M_{1}^{2}\sin^{2}\theta+5}{7M_{1}^{2}\sin^{2}\theta-1} \tag{131}$$

$$\begin{split} M_2^2 &= \frac{(\gamma+1)^2 M_1^4 \sin^2\!\theta - 4 (M_1^2 \sin^2\!\theta - 1) (\gamma M_1^2 \sin^2\!\theta + 1)}{[2\gamma M_1^2 \sin^2\!\theta - (\gamma - 1)] [(\gamma - 1) M_1^2 \sin^2\!\theta + 2]} \\ &= \frac{36 M_1^4 \sin^2\!\theta - 5 (M_1^2 \sin^2\!\theta - 1) (7 M_1^2 \sin^2\!\theta + 5)}{(7 M_1^2 \sin^2\!\theta - 1) (M_1^2 \sin^2\!\theta + 5)} \end{split} \tag{132}$$

$$\frac{\tilde{u}_2}{V_1} = \frac{(\gamma - 1)M_1^2 \sin^2 \theta + 2}{(\gamma + 1)M_1^2 \sin^2 \theta} \sin \theta = \frac{M_1^2 \sin^2 \theta + 5}{6M_1^2 \sin^2 \theta} \sin \theta$$
(133)

$$\frac{\tilde{v}_2}{V_1} = \frac{\tilde{v}_1}{V_1} = \cos \theta \tag{134}$$

$$\frac{u_2}{V_1} = 1 - \frac{2(M_1^2 \sin^2 \theta - 1)}{(\gamma + 1)M_1^2} = 1 - \frac{5(M_1^2 \sin^2 \theta - 1)}{6M_1^2}$$
(135)

$$\frac{v_2}{V_1} = \frac{2(M_1^2 \sin^2\theta - 1)}{(\gamma + 1)M_1^2} \cot \theta = \frac{5(M_1^2 \sin^2\theta - 1)}{6M_1^2} \cot \theta$$

$$\frac{V_2^2}{V_1^2} = 1 - 4 \frac{(M_1^2 \sin^2\theta - 1)(\gamma M_1^2 \sin^2\theta + 1)}{(\gamma + 1)^2 M_1^4 \sin^2\theta}$$
(136)

$$V_{1}^{2} = (\gamma + 1)^{2} M_{1}^{4} \sin^{2}\theta$$

$$= 1 - \frac{5}{36} \frac{(M_{1}^{2} \sin^{2}\theta - 1)(7M_{1}^{2} \sin^{2}\theta + 5)}{M_{1}^{4} \sin^{2}\theta}$$
(137)

$$\cot \delta = \tan \theta \left[ \frac{(\gamma + 1)M_1^2}{2(M_1^2 \sin^2 \theta - 1)} - 1 \right]$$

$$= \tan \theta \left[ \frac{6M_1^2}{5(M_1^2 \sin^2 \theta - 1)} - 1 \right]$$
(138)

$$\tan \delta = \frac{2 \cot \theta (M_1^2 \sin^2 \theta - 1)}{2 + M_1^2 (\gamma + 1 - 2 \sin^2 \theta)} = \frac{5 \cot \theta (M_1^2 \sin^2 \theta - 1)}{5 + M_1^2 (6 - 5 \sin^2 \theta)}$$
(139a)

$$= \frac{M_1^2 \sin 2\theta - 2 \cot \theta}{2 + M_1^2 (\gamma + \cos 2\theta)} = 5 \frac{M_1^2 \sin 2\theta - 2 \cot \theta}{10 + M_1^2 (7 + 5 \cos 2\theta)}$$
(139b)

$$\frac{p_2}{p_{t_1}} = \frac{2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)}{(\gamma + 1)} \left[ \frac{2}{(\gamma - 1)M_1^2 + 2} \right]^{\frac{\gamma}{\gamma - 1}}$$

$$= \frac{7M_1^2 \sin^2 \theta - 1}{6} \left( \frac{5}{M_1^2 + 5} \right)^{7/2} \tag{140}$$

$$\frac{p_2}{p_{t_2}} \!\!=\! \! \left\{ \! 2 \frac{ [2 \gamma M_1^2 \sin^2\theta \! - \! (\gamma \! - \! 1)] \left[ (\gamma \! - \! 1) M_1^2 \sin^2\theta \! + \! 2 \right] }{ (\gamma \! + \! 1)^2 M_1^2 \sin^2\theta \left[ (\gamma \! - \! 1) M_1^2 \! + \! 2 \right] } \! \right\}^{\frac{\gamma}{\gamma - 1}} \!$$

$$= \left[5 \frac{(7M_1^2 \sin^2 \theta - 1)(M_1^2 \sin^2 \theta + 5)}{36M_1^2 \sin^2 \theta(M_1^2 + 5)}\right]^{7/2}$$
(141)

$$\begin{split} &\frac{p_{t_{2}}}{p_{t_{1}}} = \frac{\rho_{t_{2}}}{\rho_{t_{1}}} = e^{-\frac{\Delta s}{R}} \\ &= \left[ \frac{(\gamma+1)M_{1}^{2} \sin^{2}\theta}{(\gamma-1)M_{1}^{2} \sin^{2}\theta+2} \right]^{\frac{\gamma}{\gamma-1}} \left[ \frac{\gamma+1}{2\gamma M_{1}^{2} \sin^{2}\theta-(\gamma-1)} \right]^{\frac{1}{\gamma-1}} \\ &= \left( \frac{6M_{1}^{2} \sin^{2}\theta}{M_{1}^{2} \sin^{2}\theta+5} \right)^{7/2} \left( \frac{6}{7M_{1}^{2} \sin^{2}\theta-(\gamma-1)} \right)^{\frac{1}{\gamma-1}} \times \\ &\frac{p_{t_{2}}}{p_{1}} = \left[ \frac{\gamma+1}{2\gamma M_{1}^{2} \sin^{2}\theta-(\gamma-1)} \right]^{\frac{1}{\gamma-1}} \times \\ &\left\{ \frac{(\gamma+1)M_{1}^{2} \sin^{2}\theta-(\gamma-1)}{2[(\gamma-1)M_{1}^{2} \sin^{2}\theta+2]} \right\}^{\frac{\gamma}{\gamma-1}} \\ &= \left( \frac{6}{7M_{1}^{2} \sin^{2}\theta-1} \right)^{5/2} \left[ \frac{6M_{1}^{2} \sin^{2}\theta(M_{1}^{2}+5)}{5(M_{1}^{2} \sin^{2}\theta+5)} \right]^{7/2} \\ &= \left( \frac{6}{7M_{1}^{2} \sin^{2}\theta-1} \right)^{5/2} \left[ \frac{6M_{1}^{2} \sin^{2}\theta(M_{1}^{2}+5)}{5(M_{1}^{2} \sin^{2}\theta+5)} \right]^{7/2} \\ &= \ln \left[ \frac{2\gamma M_{1}^{2} \sin^{2}\theta-(\gamma-1)}{\gamma+1} \right] - \\ &\gamma \ln \left[ \frac{(\gamma+1)M_{1}^{2} \sin^{2}\theta}{(\gamma-1)M_{1}^{2} \sin^{2}\theta+2} \right] \\ &= \ln \left( \frac{7M_{1}^{2} \sin^{2}\theta-1}{6} \right) - \frac{7}{5} \ln \left( \frac{6M_{1}^{2} \sin^{2}\theta}{M_{1}^{2} \sin^{2}\theta+5} \right) \end{aligned} \tag{144} \end{split}$$

$$\frac{p_2 - p_1}{q_1} = \frac{4(M_1^2 \sin^2 \theta - 1)}{(\gamma + 1)M_1^2} = \frac{5}{3} \frac{M_1^2 \sin^2 \theta - 1}{M_1^2}$$
(145)

Values of the following ratios for oblique shock waves can be read from table II, provided  $M_1 \sin \theta$  is used instead of  $M_1$  in the first column:

$$\frac{p_2}{p_1}, \frac{\rho_2}{\rho_1}, \frac{T_2}{T_1}, \frac{p_{t_2}}{p_{t_1}}$$

For weak shock waves  $(M_1 \sin \theta)$  only slightly greater than unity) the following series are obtained from equations (103) and (104) by replacing  $M_1$  by  $M_1 \sin \theta$ :

$$\frac{p_{t_2}}{p_{t_1}} = 1 - \frac{2\gamma}{3(\gamma+1)^2} (M_1^2 \sin^2 \theta - 1)^3 + \frac{2\gamma^2}{(\gamma+1)^3} (M_1^2 \sin^2 \theta - 1)^4 + \dots 
= 1 - \frac{35}{216} (M_1^2 \sin^2 \theta - 1)^3 + \frac{245}{864} (M_1^2 \sin^2 \theta - 1)^4 + \dots (146)$$

$$\frac{\Delta s}{R} = \frac{1}{\gamma - 1} \frac{\Delta s}{c_v} = \frac{2\gamma}{3(\gamma+1)^2} (M_1^2 \sin^2 \theta - 1)^3 - \frac{2\gamma^2}{(\gamma+1)^3} (M_1^2 \sin^2 \theta - 1)^4 + \dots$$

$$= \frac{35}{216} (M_1^2 \sin^2 \theta - 1)^3 - \frac{245}{864} (M_1^2 \sin^2 \theta - 1)^4 + \dots (147)$$

#### Parameters $\theta$ and $\delta$ .—

$$\frac{1}{M_1^2} = \sin^2 \theta - \frac{\gamma + 1}{2} \frac{\sin \theta \sin \delta}{\cos (\theta - \delta)} = \sin^2 \theta - \frac{\gamma + 1}{2} \frac{\tan \delta}{\tan \delta + \cot \theta}$$

$$= \sin^2 \theta - \frac{\gamma + 1}{2} \frac{\tan \theta}{\tan \theta + \cot \delta}$$
(148a)

$$M_1^2 = \frac{2(\cot \theta + \tan \delta)}{\sin 2\theta - \tan \delta(\gamma + \cos 2\theta)}$$

$$10(\cot \theta + \tan \delta)$$

$$= \frac{10(\cot \theta + \tan \delta)}{5\sin 2\theta - \tan \delta (7 + 5\cos 2\theta)}$$
(148b)

$$\frac{p_2 - p_1}{q_1} = 2 \frac{\sin \theta \sin \delta}{\cos (\theta - \delta)}$$

$$=2\frac{\tan\delta}{\tan\delta + \cot\theta} = 2\frac{\tan\theta}{\tan\theta + \cot\delta}$$
 (149a)

$$\frac{\rho_2 - \rho_1}{\rho_2} = \frac{\sin \delta}{\sin \theta \cos (\theta - \delta)} \tag{149b}$$

#### Parameters $M_1$ and $\delta$ .—

No convenient explicit relations exist. However, the value of  $\sin^2 \theta$  can be found by solving the following cubic equation (ref. 12):

$$\sin^6 \theta + b \sin^4 \theta + c \sin^2 \theta + d = 0 \tag{150a}$$

where

$$b = -\frac{M_1^2 + 2}{M_1^2} - \gamma \sin^2 \delta$$

$$c = \frac{2M_1^2 + 1}{M_1^4} + \left[ \frac{(\gamma + 1)^2}{4} + \frac{\gamma - 1}{M_1^2} \right] \sin^2 \delta$$

$$d = -\frac{\cos^2 \delta}{M_1^4}$$
(150b)

The smallest of the three roots corresponds to a decrease in entropy and should be disregarded.

For weak shock waves (small deflections  $\delta$ ) the following series are useful (note that  $\delta$  must be measured in radians):

$$\frac{p_{2}}{p_{1}} = 1 + \frac{\gamma M_{1}^{2}}{(M_{1}^{2} - 1)^{1/2}} \delta + \gamma M_{1}^{2} \frac{(\gamma + 1)M_{1}^{4} - 4(M_{1}^{2} - 1)}{4(M_{1}^{2} - 1)^{2}} \delta^{2} + \frac{\gamma M_{1}^{2}}{(M_{1}^{2} - 1)^{7/2}} \left[ \frac{(\gamma + 1)^{2}}{32} M_{1}^{8} - \frac{7 + 12\gamma - 3\gamma^{2}}{24} M_{1}^{6} + \frac{3}{4} (\gamma + 1)M_{1}^{4} - M_{1}^{2} + \frac{2}{3} \right] \delta^{3} + \dots$$
(151)
$$\frac{p_{2} - p_{1}}{q_{1}} = \frac{2}{(M_{1}^{2} - 1)^{1/2}} \delta + \frac{(\gamma + 1)M_{1}^{4} - 4(M_{1}^{2} - 1)}{2(M_{1}^{2} - 1)^{2}} \delta^{2} + \frac{1}{(M_{1}^{2} - 1)^{7/2}} \left[ \frac{(\gamma + 1)^{2}}{16} M_{1}^{8} - \frac{7 + 12\gamma - 3\gamma^{2}}{12} M_{1}^{6} + \frac{3}{2} (\gamma + 1)M_{1}^{4} - 2M_{1}^{2} + \frac{4}{3} \right] \delta^{3} + \dots$$
(152)

$$\frac{\rho_{2}}{\rho_{1}} = 1 + \frac{M_{1}^{2}}{(M_{1}^{2} - 1)^{1/2}} \delta + M_{1}^{2} \frac{(3 - \gamma)M_{1}^{2}(M_{1}^{2} - 2) + 4}{4(M_{1}^{2} - 1)^{2}} \delta^{2} + \dots$$

$$\frac{T_{2}}{T_{1}} = 1 + \frac{(\gamma - 1)M_{1}^{2}}{(M_{1}^{2} - 1)^{1/2}} \delta + \dots$$

$$(\gamma - 1)M_{1}^{2} \frac{(\gamma + 1)M_{1}^{4} - 2(M_{1}^{2} + 2)(M_{1}^{2} - 1)}{4(M_{1}^{2} - 1)^{2}} \delta^{2} + \dots$$
(154)

Since flow through weak shock waves is nearly insentropic, compressions through small angles can also be calculated with the aid of table II by regarding them as reversed Prandtl-Meyer expansions (see later section). The resulting numerical accuracy is greater than that obtained by retaining terms up to  $\delta^2$  in the above series, and nearly equal to that obtained by retaining terms up to  $\delta^3$ .

Charts 2, 3, and 4 show the variation of shock-wave angle, pressure coefficient across a shock wave, and downstream Mach number with flow-deflection angle for various upstream Mach numbers.

#### Parameter $\xi \equiv p_2/p_1$ .—

$$M_1^2 \sin^2 \theta = \frac{(\gamma+1)\xi + (\gamma-1)}{2\gamma} = \frac{6\xi + 1}{7}$$
 (155)

$$M_2^2 \sin^2(\theta - \delta) = \frac{(\gamma - 1)\xi + (\gamma + 1)}{2\gamma\xi} = \frac{\xi + 6}{7\xi}$$
 (156)

$$M_{2}^{2} = \frac{M_{1}^{2}[(\gamma+1)\xi+(\gamma-1)]-2(\xi^{2}-1)}{\xi[(\gamma-1)\xi+(\gamma+1)]}$$

$$= \frac{M_{1}^{2}(6\xi+1)-5(\xi^{2}-1)}{\xi(\xi+6)}$$
(157)

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)\xi + (\gamma-1)}{(\gamma-1)\xi + (\gamma+1)} = \frac{6\xi+1}{\xi+6}$$
 (158)

$$\frac{T_2}{T_1} = \frac{a_2^2}{a_1^2} = \xi \frac{(\gamma - 1)\xi + (\gamma + 1)}{(\gamma + 1)\xi + (\gamma - 1)} = \xi \frac{\xi + 6}{6\xi + 1}$$
(159)

$$\begin{split} \tan^2\delta \!=\! \! \left( \frac{\xi \! - \! 1}{\gamma M_1{}^2 \! - \! \xi \! + \! 1} \right)^2 \frac{2\gamma M_1{}^2 \! - \! (\gamma \! - \! 1) \! - \! (\gamma \! + \! 1)\xi}{(\gamma \! + \! 1)\xi \! + \! (\gamma \! - \! 1)} \\ =\! \! \left[ \frac{5(\xi \! - \! 1)}{7M_1{}^2 \! - \! 5(\xi \! - \! 1)} \right]^2 \frac{7M_1{}^2 \! - \! (6\xi \! + \! 1)}{6\xi \! + \! 1} \quad (160) \end{split}$$

$$\frac{p_{t_2}}{p_{t_1}} = \frac{\rho_{t_2}}{\rho_{t_1}} = e^{-\frac{\Delta s}{R}} = \left[ \frac{(\gamma + 1)\xi + (\gamma - 1)}{(\gamma - 1)\xi + (\gamma + 1)} \right]^{\frac{\gamma}{\gamma - 1}} \xi^{-\frac{1}{\gamma - 1}}$$

$$= \left( \frac{6\xi + 1}{\xi + 6} \right)^{7/2} \xi^{-5/2} \tag{161}$$

$$\frac{V_2^2}{V_1^2} = 1 - \frac{2(\xi^2 - 1)}{M_1^2[(\gamma + 1)\xi + (\gamma - 1)]} = 1 - \frac{5(\xi^2 - 1)}{M_1^2(6\xi + 1)}$$
(162)

For weak shock waves, equations (113) and (114) apply to oblique as well as normal shocks.

#### SHOCK POLAR

The velocities associated with an oblique shock wave are conveniently represented in the velocity-vector (hodograph) plane. For a given Mach number ahead of the shock wave, all possible velocity vectors behind the shock lie on a single curve.

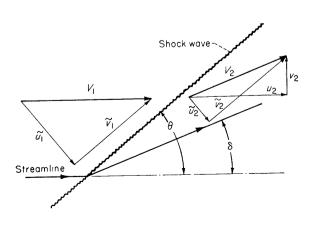
Only the closed loop represents real shock waves with nondecreasing entropy, and forms Busemann's shock polar (fig. 3). Its equation is

$$v_{2}^{2} = (V_{1} - u_{2})^{2} \frac{u_{2} - \frac{a_{*}^{2}}{V_{1}}}{\frac{2}{\gamma + 1} V_{1} + \frac{a_{*}^{2}}{V_{1}} - u_{2}}$$
(163)

Other forms of this equation convenient for computation are, given  $V_1$  and  $M_1$ ,

$$\left(\frac{v_{\scriptscriptstyle 2}}{V_{\scriptscriptstyle 1}}\right)^{\!2}\!=\!\left(1\!-\!\frac{u_{\scriptscriptstyle 2}}{V_{\scriptscriptstyle 1}}\right)^{\!2}\frac{(M_{\scriptscriptstyle 1}{}^2\!-\!1)\!-\!\frac{\gamma+1}{2}\,M_{\scriptscriptstyle 1}{}^2\left(1\!-\!\frac{u_{\scriptscriptstyle 2}}{V_{\scriptscriptstyle 1}}\right)}{1\!+\!\frac{\gamma+1}{2}\,M_{\scriptscriptstyle 1}{}^2\left(1\!-\!\frac{u_{\scriptscriptstyle 2}}{V_{\scriptscriptstyle 1}}\right)}$$

$$= \left(1 - \frac{u_2}{V_1}\right)^2 \frac{5(M_1^2 - 1) - 6M_1^2 \left(1 - \frac{u_2}{V_1}\right)}{5 + 6M_1^2 \left(1 - \frac{u_2}{V_1}\right)} \quad (164a)$$



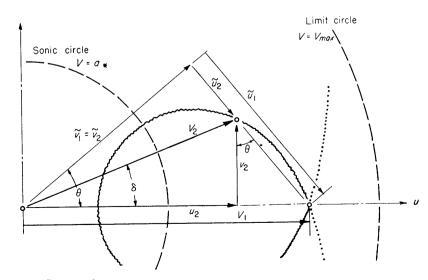


FIGURE 3.—Shock polar.

given  $a_*$  and  $V_1$ ,

$$\left(\frac{V_2}{a_*}\right)^2 = \left(\frac{V_1}{a_*} - \frac{u_2}{a_*}\right)^2 \frac{\frac{V_1}{a_*} \frac{u_2}{a_*} - 1}{1 + \frac{2}{\gamma + 1} \left(\frac{V_1}{a_*}\right)^2 - \frac{V_1}{a_*} \frac{u_2}{a_*}}$$

$$= \left(\frac{V_1}{a_*} - \frac{u_2}{a_*}\right)^2 \frac{6\left(\frac{V_1}{a_*} \frac{u_2}{a_*} - 1\right)}{5\left(\frac{V_1}{a_*}\right)^2 - 6\left(\frac{V_1}{a_*} \frac{u_2}{a_*} - 1\right)} \tag{164b}$$

and given  $V_1$  and  $V_m$ ,

$$\left(\frac{v_2}{V_m}\right)^2 = \left(\frac{V_1}{V_m} - \frac{u_2}{V_m}\right)^2 \frac{\frac{V_1}{V_m} \frac{u_2}{V_m} - \frac{\gamma - 1}{\gamma + 1}}{\frac{2}{\gamma + 1} \left(\frac{V_1}{V_m}\right)^2 + \frac{\gamma - 1}{\gamma + 1} - \frac{V_1}{V_m} \frac{u_2}{V_m}}$$

$$= \left(\frac{V_1}{V_m} - \frac{u_2}{V_m}\right)^2 \frac{\left(6\frac{V_1}{V_m}\frac{u_2}{V_m} - 1\right)}{5\left(\frac{V_1}{V_m}\right)^2 - \left(6\frac{V_1}{V_m}\frac{u_2}{V_m} - 1\right)} (164c)$$

The shock-wave angle  $\theta$  and wedge angle  $\delta$  are given in terms of the velocity components by

$$\tan \theta = \frac{V_1 - u_2}{v_2} = \frac{\tilde{u}_1}{\tilde{v}_1}$$
 (165)

$$\tan \delta = \frac{v_2}{u_2} \tag{166}$$

The shock-wave angle  $\theta_*$  for sonic flow behind the shock is found (by setting  $M_2=1$  in eq. (132)) to be given by

$$\begin{split} \sin^2 \theta_* &= \frac{1}{4\gamma M_1^2} \{ (\gamma + 1) M_1^2 - (3 - \gamma) + \\ & \sqrt{(\gamma + 1)[(\gamma + 1) M_1^4 - 2(3 - \gamma) M_1^2 + (\gamma + 9)]} \} \\ &= \frac{1}{7M_1^2} \left[ 3 M_1^2 - 2 + \sqrt{3(3 M_1^4 - 4 M_1^2 + 13)} \right] \end{split} \tag{167}$$

The shock-wave angle  $\theta_{b_{max}}$  for maximum stream deflection behind the shock is given by

$$\sin^{2} \theta_{\delta_{max}} = \frac{1}{4\gamma M_{1}^{2}} \{ (\gamma + 1) M_{1}^{2} - 4 + \sqrt{(\gamma + 1) [(\gamma + 1) M_{1}^{4} + 8 (\gamma - 1) M_{1}^{2} + 16]} \} 
= \frac{1}{7 M_{1}^{2}} [3 M_{1}^{2} - 5 + \sqrt{3} (3 M_{1}^{4} + 4 M_{1}^{2} + 20)]$$
(168)

For small deflection angles (hence Mach numbers close to unity), the deflection angle (radians) for sonic flow behind the shock is given approximately in terms of the upstream Mach number by

$$\delta_* = \frac{1}{\sqrt{2} (\gamma + 1)} \frac{(M_1^2 - 1)^{3/2}}{M_1^2} = 0.2946 \frac{(M_1^2 - 1)^{3/2}}{M_1^2} \quad (169)$$

The maximum stream deflection angle for a specified upstream Mach number is given approximately by

$$\delta_{max} = \frac{4}{3\sqrt{3}(\gamma+1)} \frac{(M_1^2 - 1)^{3/2}}{M_1^2} = 0.3208 \frac{(M_1^2 - 1)^{3/2}}{M_1^2} \quad (170)$$

In unsteady flow all the above relations are valid across a moving oblique shock wave if instantaneous velocities are measured relative to the shock.

#### SUPERSONIC FLOW PAST WEDGES AND CONES

A shock wave forms ahead of any body in supersonic flight and remains fixed relative to the body if the flight is steady. It stands ahead of blunt shapes, but may be attached to pointed shapes.

Just at the tip of a pointed airfoil or body of revolution the flow is the same as for the initially tangent wedge or cone. The bow wave is attached at sufficiently high Mach numbers for a wedge of semivertex angle  $\delta$  less than  $\sin^{-1}(1/\gamma)\!=\!45.6^\circ$ for  $\gamma = 7/5$ , and for a circular cone of semivertex angle  $\sigma$  less than  $57.5^{\circ}$  for  $\gamma=1.405$ . Below these limits, the wave is attached above a minimum Mach number whose dependence upon nose angle is shown for wedges and cones in figure 4. (These values can be applied to pointed airfoils and bodies of revolution which are not concave.) Also shown in figure 4 are the slightly higher Mach numbers above which the velocity behind the shock wave is supersonic, and for the cone the still higher Mach number above which the flow is supersonic even at the surface. (For wedges these last two coincide.) For thin wedges, these Mach numbers are given approximately by equations (169) and (170).

#### FLOW PAST WEDGES

If the bow shock wave is attached to a wedge, it is straight, and the flow behind the shock consists of uniform streams parallel to either face of the wedge. The flow pattern above the upper face (fig. 5) may be regarded as obtained from the straight oblique shock-wave pattern of figure 2 by replacing the streamline behind the shock wave with a solid wall. Flow quantities are determined by the oblique-shock-wave relations, equations (115) to (170). As noted previously, table II can also be applied if  $M_1 \sin \theta$  is used in place of  $M_1$  in the first column.

The flows above and below the wedge are independent, so that inclined wedges can be treated if neither face exceeds the attachment angle shown in figure 4. However, if the angle of attack exceeds the semivertex angle, the flow over the upper (leeward) surface is given by a Prandtl-Meyer expansion (see fig. 4) rather than by the shock relations.

It is clear from the shock polar (fig. 3) that two different shock waves and flow patterns are theoretically possible for a given wedge and Mach number. However, it is believed that only the weaker shock wave (larger  $u_2$  and smaller  $\theta$ ) can occur attached to an isolated convex body.

Charts 2, 3, and 4 show the dependence of shock-wave angle, surface pressure coefficient, and downstream Mach number upon wedge angle for various free-stream Mach numbers.

#### FLOW PAST CONES

If the bow shock wave is attached to an uninclined circular cone, the shock wave too has the form of a circular cone. Flow quantities are constant on all concentric conical surfaces lying between the shock wave and the body, and so depend upon only one space variable. The transition across the shock wave is governed by the oblique-shock relations,

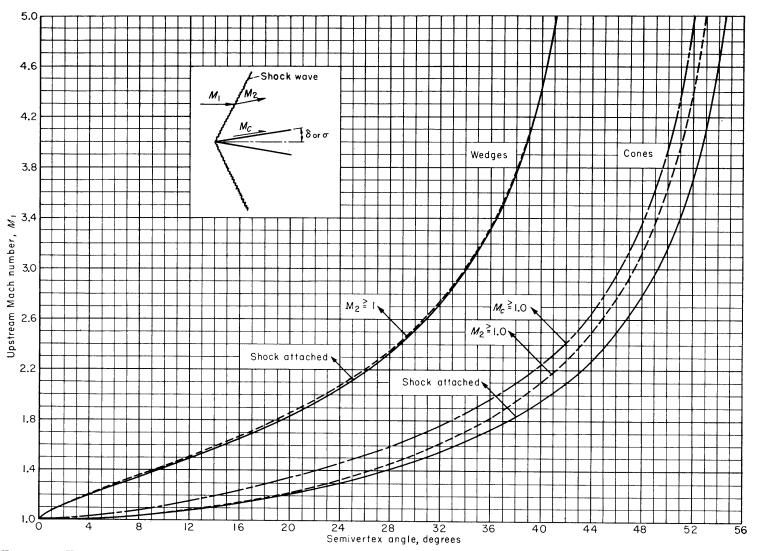


FIGURE 4.—Upstream Mach numbers for shock attachment and for supersonic flow behind shock wave on wedges and cones, and for supersonic flow at surface of cones.

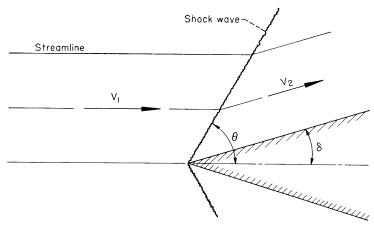


FIGURE 5.—Flow past a wedge.

and is followed by a continuous isentropic compression to surface conditions, as indicated in figure 6. The flow quantities have been extensively tabulated in reference 6 for  $\gamma=1.405$  and for  $\gamma=4/3$ . As in the case of wedges, two solutions exist for each cone and Mach number, but it is believed that only the weaker shock wave can occur on an isolated convex body. Charts 5, 6, and 7 show the dependence of shock-wave angle, surface-pressure coefficient, and

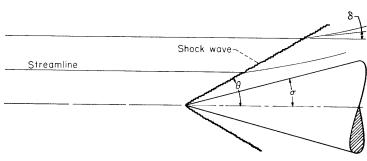


FIGURE 6.—Flow past a cone.

surface Mach number on cone semivertex angle for various free-stream Mach numbers.

The effects of slightly inclining a cone have been considered by Stone (ref. 13) and numerical results are tabulated in reference 14. Chart 8 shows the variation with Mach number of the initial slope of the normal-force curve for various cone angles. Stone has also sought an approximation for larger inclinations by retaining squares as well as first powers of angle of attack (ref. 15), and numerical results have been tabulated (ref. 16); however, these results are not free of error (see refs. 17 and 18).

#### PRANDTL-MEYER EXPANSION

A uniform two-dimensional supersonic stream flowing over a convex bend expands isentropically. Convenient relations are found by considering the special case of a stream at Mach number unity flowing around a sharp corner (fig. 7).

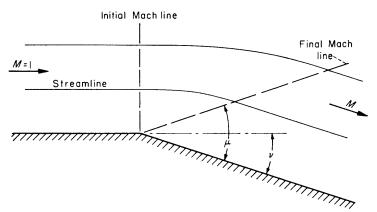


FIGURE 7.—Prandtl-Meyer expansion around a corner.

For a perfect gas, the Prandtl-Meyer angle  $\nu$  through which the stream turns in expanding from M=1 to a supersonic Mach number M is

$$\nu = \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1} \sqrt{\frac{\gamma - 1}{\gamma + 1}} (M^{2} - 1) - (90^{\circ} - \mu) \qquad (171a)$$

$$= \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1} \sqrt{\frac{\gamma - 1}{\gamma + 1}} (M^{2} - 1) - \cos^{-1} \frac{1}{M} \qquad (171b)$$

$$= \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1} \sqrt{\frac{\gamma - 1}{\gamma + 1}} (M^{2} - 1) - \tan^{-1} \sqrt{M^{2} - 1} \qquad (171c)$$

(For 
$$\gamma = 7/5$$
,  $\sqrt{\frac{\gamma+1}{\gamma-1}} = 2.4495$ , and  $\sqrt{\frac{\gamma-1}{\gamma+1}} = 0.40825$ .) The

maximum expansion angle, for  $M = \infty$ , is

$$\nu_{max} = \left(\sqrt{\frac{\gamma+1}{\gamma-1}} - 1\right) \times 90^{\circ} = 130.45^{\circ} \text{ for } \gamma = 7/5 \quad (172)$$

The ratio of static to total pressure, corresponding to Mach number M is given by

$$\frac{\left(\frac{p}{p_{t}}\right)^{\frac{\gamma-1}{\gamma}}}{=} \frac{1}{\gamma+1} \left\{ 1 + \cos \left[ 2\sqrt{\frac{\gamma-1}{\gamma+1}} \left(\nu + 90^{\circ} - \mu\right) \right] \right\} \qquad (173a)$$

$$= \frac{1}{\gamma+1} \left\{ 1 + \cos \left[ 2\sqrt{\frac{\gamma-1}{\gamma+1}} \left(\nu + \cos^{-1}\frac{1}{M}\right) \right] \right\} \qquad (173b)$$

$$= \frac{1}{\gamma+1} \left\{ 1 + \cos \left[ 2\sqrt{\frac{\gamma-1}{\gamma+1}} \left(\nu + \tan^{-1}\sqrt{M^{2}-1}\right) \right] \right\} \qquad (173c)$$

which falls to zero as  $\nu \rightarrow \nu_{max}$ . Numerical values of  $\nu$ ,  $\mu$ , and  $p/p_t$  are given in table II as functions of M.

These relations and the values in table II apply to a uniform stream flowing past any convex surface in the ab-

sence of external disturbances. (They also give a very good approximation at all Mach numbers when, as on an airfoil, external disturbances arise only from interaction with a shock wave, and are disregarded.) If flow quantities are known at one point, the values at any second point can be read from table II by identifying the change in flow angle between the two points with  $\Delta \nu = \nu_2 - \nu_1$ , as indicated in figure 8.

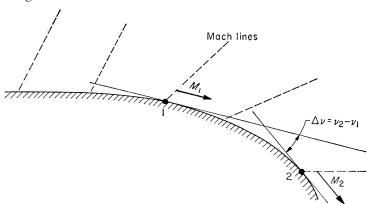


FIGURE 8.—Prandtl-Meyer expansion over a convex surface.

For expansions through small angles  $\Delta \nu$ , the ratio of final to initial static pressures is given by the following series ( $\Delta \nu$  in radians):

$$\frac{p_{2}}{p_{1}} = 1 - \frac{\gamma M_{1}^{2}}{\sqrt{M_{1}^{2} - 1}} (\Delta \nu) + \gamma M_{1}^{2} \frac{(\gamma + 1) M_{1}^{4} - 4 (M_{1}^{2} - 1)}{4(M_{1}^{2} - 1)^{2}} (\Delta \nu)^{2} - \frac{\gamma M_{1}^{2}}{2 (M_{1}^{2} - 1)^{7/2}} \left[ \frac{\gamma + 1}{6} M_{1}^{8} - \frac{5 + 7\gamma - 2\gamma^{2}}{6} M_{1}^{6} + \frac{5}{3} (\gamma + 1) M_{1}^{4} - 2M_{1}^{2} + \frac{4}{3} \right] (\Delta \nu)^{3} + \dots (174)$$

Up to and including the term in  $(\Delta \nu)^2$  this series is identical with that for compression through an oblique shock wave (eq. (151) with  $\delta = -\Delta \nu$ ).

#### **IMPERFECT-GAS EFFECTS**

Methods for calculating the flow of a calorically imperfect, thermally imperfect gas and a calorically imperfect, thermally perfect gas at temperatures up to 5000° R are described in this section. The equations presented are in substantially the same form as those given in references 7 and 8. Effects of gaseous imperfections, such as molecular dissociation, which become important at temperatures greater than about 5000° R are not considered.

Atmospheric and wind-tunnel air flows are of primary concern here. In such flows air generally exhibits only caloric imperfections to any appreciable degree. Consequently, numerical results are presented only for the flow of a calorically imperfect, thermally perfect diatomic gas.

#### THERMODYNAMICS

#### EQUATIONS OF STATE

The thermal equation of state used here for a calorically and thermally imperfect gas is the Berthelot equation

(eq. (5)). The thermal equation of state used for a calorically imperfect, thermally perfect gas is equation (2). The caloric equation of state used for a calorically and thermally imperfect gas is equation (8a). The caloric equation of state used for a calorically imperfect, thermally perfect gas is equation (8b).

#### SPECIFIC HEATS

The assumption of a simple harmonic vibrator is used to account for the contribution of the vibrational heat capacity to the specific heats. The equations for the specific heats at constant volume and constant pressure, respectively, are (see ref. 7)

$$c_v = (c_v)_{\text{perf}} \left\{ 1 + (\gamma_{\text{perf}} - 1) \left[ \left( \frac{\Theta}{T} \right)^2 \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^2} + \frac{2c\rho}{RT^2} \right] \right\}$$
(175)

$$c_{v} = (c_{v})_{\text{perf}} \left\{ 1 + (\gamma_{\text{perf}} - 1) \left[ \left( \frac{\Theta}{T} \right)^{2} \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^{2}} \right] \right\} [\text{therm perf}]$$
(176)

$$c_{p} = (c_{p})_{perf} \left\{ 1 + \frac{\gamma_{perf} - 1}{\gamma_{perf}} \left[ \left( \frac{\Theta}{T} \right)^{2} \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^{2}} + \frac{2c_{\rho}}{RT^{2}} \left\{ 1 + \frac{\frac{2 - b_{\rho}}{1 - b_{\rho}} + \frac{c_{\rho}}{2RT^{2}}}{\frac{1}{(1 - b_{\rho})^{2}} - \frac{2c_{\rho}}{RT^{2}}} \right] \right\}$$
(177)

$$c_p = (c_p)_{\text{perf}} \left\{ 1 + \frac{\gamma_{\text{perf}} - 1}{\gamma_{\text{perf}}} \left[ \left( \frac{\Theta}{T} \right)^2 \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^2} \right] \right\} [\text{therm perf}]$$
(178)

The ratio of specific heats is then

$$\gamma = \gamma_{perf} \times$$

$$\begin{bmatrix}
1 + \frac{\gamma_{\text{perf}} - 1}{\gamma_{\text{perf}}} \left\{ \left(\frac{\theta}{T}\right)^2 \frac{e^{\theta/T}}{(e^{\theta/T} - 1)^2} + \frac{2c\rho}{RT^2} \left[ 1 + \frac{\frac{2 - b\rho}{1 - b\rho} + \frac{c\rho}{2RT^2}}{\frac{1}{(1 - b\rho)^2} - \frac{2c\rho}{RT^2}} \right] \right\} \\
1 + (\gamma_{\text{perf}} - 1) \left[ \left(\frac{\theta}{T}\right)^2 \frac{e^{\theta/T}}{(e^{\theta/T} - 1)^2} + \frac{2c\rho}{RT^2} \right]$$
The integrated forms of the energy equation at 
$$V^2 = 2RT_t \left[ \frac{1 - \frac{T}{T_t}}{\gamma_{\text{perf}} - 1} + \frac{\theta}{T_t} \left( \frac{1}{e^{\theta/T_t} - 1} - \frac{1}{e^{\theta/T_t} - 1} \right) + \frac{2c\rho}{RT^2} \right]$$

$$(179)$$

$$\frac{2c}{RT} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) + \frac{1}{RT_t} \left( \frac{\rho_t}{T_t} - \frac{\rho}{T_t} \right) \right] \left[ \frac{2c\rho}{RT_t} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) + \frac{1}{RT_t} \left( \frac{\rho_t}{T_t} - \frac{\rho}{T_t} \right) \right] \left[ \frac{2c\rho}{RT_t} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) + \frac{1}{RT_t} \left( \frac{\rho_t}{T_t} - \frac{\rho}{T_t} \right) \right] \left[ \frac{2c\rho}{RT_t} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) + \frac{1}{RT_t} \left( \frac{\rho_t}{T_t} - \frac{\rho}{T_t} \right) \right] \left[ \frac{2c\rho}{RT_t} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) \right] \left[ \frac{2c\rho}{T_t} \left( \frac{\rho}{T_t} - \frac{\rho_t}{T_t} \right) \right] \left[$$

or, for a thermally perfect gas,

$$\gamma = 1 + \frac{\gamma_{\text{perf}} - 1}{1 + (\gamma_{\text{perf}} - 1) \left[ \left( \frac{\Theta}{T} \right)^2 \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^2} \right]} [\text{therm perf}] \quad (180)$$

The following values of  $\gamma$  are for temperatures from 400° R to  $5000^{\circ}$  R, with  $\theta = 5500^{\circ}$  R (see ref. 7). For engineering purposes, these are a satisfactory approximation for air.

VAF	RIATION OI	F RATIO OF TEMPER		HEATS W	ITH
T, °R	γ	T, °R	γ	T, °R	γ
500 600 700	1, 400 1, 399 1, 396	1300 1400 1500	1. 361 1. 355 1. 349	2200 2400 2600	1. 322 1. 317 1. 318
800 900	1. 392 1. 387	1600 1700 1800	1. 344 1. 339 1. 335	2800 3000 3500	1, 309 1, 306 1, 30
1000 1100 1200	1, 381 1, 375 1, 368	1900 1900 2000	1. 331 1. 328	4000 4500 5000	1, 298 1, 296 1, 296

#### CONTINUOUS ONE-DIMENSIONAL FLOW BASIC EQUATIONS AND DEFINITIONS

Basic equations pertinent to this section are equations (26), (27), (28), (29), (30), and (31). The equations for the speed of sound are (see ref. 7)

$$a^{2} = RT \left\{ \frac{1}{(1 - b\rho)^{2}} - \frac{2c\rho}{RT^{2}} + \frac{(\gamma_{perf} - 1)\left(\frac{c\rho}{RT^{2}} + \frac{1}{1 - b\rho}\right)^{2}}{1 + (\gamma_{perf} - 1)\left[\left(\frac{\theta}{T}\right)^{2} \frac{e^{\theta/T}}{(e^{\theta/T} - 1)^{2}} + \frac{2c\rho}{RT^{2}}\right]} \right\}$$
(181)

$$a^{2} = RT \left\{ 1 + \frac{\gamma_{\text{perf}} - 1}{\left[ 1 + (\gamma_{\text{perf}} - 1) \left( \frac{\Theta}{T} \right)^{2} \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^{2}} \right]} \right\}$$
 [therm perf] (182)

#### INTEGRATED FORMS OF ENERGY EQUATION

The integrated forms of the energy equation are (see ref. 7)

$$V^{2} = 2RT_{t} \left[ \frac{1 - \frac{T}{T_{t}}}{\gamma_{\text{pert}} - 1} + \frac{\Theta}{T_{t}} \left( \frac{1}{e^{\Theta/T_{t}} - 1} - \frac{1}{e^{\Theta/T} - 1} \right) + \frac{2c}{RT_{t}} \left( \frac{\rho}{T} - \frac{\rho_{t}}{T_{t}} \right) + \frac{1}{RT_{t}} \left( \frac{p_{t}}{\rho_{t}} - \frac{p}{\rho} \right) \right] \text{ [adiab]} \quad (183)$$

and

$$V^{2} = 2RT_{t} \left[ \frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1} \left( 1 - \frac{T}{T_{t}} \right) + \frac{\theta}{T_{t}} \left( \frac{1}{e^{\theta/T_{t}} - 1} - \frac{1}{e^{\theta/T_{t}} - 1} \right) \right] \quad \text{[adiab, therm perf]} \quad (184)$$

In terms of Mach number these equations become, respectively,

$$M^{2} = \frac{2T_{t} \left[ \frac{1 - \frac{T}{T_{t}}}{\gamma_{\text{pert}} - 1} + \frac{\Theta}{T_{t}} \left( \frac{1}{e^{\Theta/T_{t}} - 1} - \frac{1}{e^{\Theta/T} - 1} \right) + \frac{2c}{RT_{t}} \left( \frac{\rho}{T} - \frac{\rho_{t}}{T_{t}} \right) + \frac{1}{RT_{t}} \left( \frac{p_{t}}{\rho_{t}} - \frac{p}{\rho} \right) \right]}{T \left\{ \frac{1}{(1 - b\rho)^{2}} - \frac{2c\rho}{RT^{2}} + \frac{(\gamma_{\text{pert}} - 1)\left( \frac{c\rho}{RT^{2}} + \frac{1}{1 - b\rho} \right)^{2}}{1 + (\gamma_{\text{pert}} - 1)\left[ \left( \frac{\Theta}{T} \right)^{2} \frac{e^{\Theta/T}}{(e^{\Theta/T} - 1)^{2}} + \frac{2c\rho}{RT^{2}} \right] \right\}}$$
 [adiab] (185)

and

$$M^{2} = \frac{2T_{t}}{\gamma T} \left[ \frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1} \left( 1 - \frac{T}{T_{t}} \right) + \frac{\theta}{T_{t}} \left( \frac{1}{e^{\theta/T_{t}} - 1} - \frac{1}{e^{\theta/T} - 1} \right) \right] \quad [\text{adiab, therm perf}]$$

$$(186)$$

where  $\gamma$  is given by equation (180).

The variations of  $\frac{\left(\frac{V}{a_*}\right)_{\text{therm perf}}}{\left(\frac{V}{a_*}\right)_{\text{perf}}}$  and  $\frac{\left(\frac{T}{T_t}\right)_{\text{therm perf}}}{\left(\frac{T}{T_t}\right)_{\text{perf}}}$  with Mach number for several values of total temperature  $T_t$  are given in

charts 9 and 10.

#### PRESSURE AND DENSITY RELATIONS

For isentropic flow, the relations between density and temperature are (see ref. 7)

$$\left(\frac{\rho}{\rho_t}\right)\left(\frac{1-b\rho_t}{1-b\rho}\right) = \left(\frac{e^{\Theta/T_t}-1}{e^{\Theta/T}-1}\right)\left(\frac{T}{T_t}\right)^{\frac{1}{\gamma_{\text{perf}}-1}} \exp\left[\frac{c\rho_t}{RT_t^2} - \frac{c\rho}{RT^2} + \left(\frac{\Theta}{T}\right)\frac{e^{\Theta/T}}{e^{\Theta/T}-1} - \left(\frac{\Theta}{T_t}\right)\frac{e^{\Theta/T_t}}{e^{\Theta/T_t}-1}\right] \quad \text{[isen]}$$

and, for a thermally perfect gas,

$$\frac{\rho}{\rho_t} = \left(\frac{e^{\Theta/T_t} - 1}{e^{\Theta/T} - 1}\right) \left(\frac{T}{T_t}\right)^{\frac{1}{\gamma_{pert} - 1}} \exp\left[\left(\frac{\Theta}{T}\right) \frac{e^{\Theta/T}}{e^{\Theta/T} - 1} - \left(\frac{\Theta}{T_t}\right) \frac{e^{\Theta/T_t}}{e^{\Theta/T_t} - 1}\right] \quad [\text{isen, therm perf}]$$
(188)

The variation of  $\frac{\left(\frac{\rho}{\rho_t}\right)_{\text{therm perf}}}{\left(\frac{\rho}{\rho_t}\right)_{\text{perf}}}$  with Mach number for several total temperatures is presented in chart 11.

For the isentropic flow of a thermally imperfect, calorically imperfect gas, the relation between pressure, density, and temperature can be obtained by a trial-and-error procedure using equations (5) and (187).<sup>5</sup> For the isentropic flow of a thermally perfect gas, the relation between pressure and temperature is

$$\frac{p}{p_t} = \left(\frac{e^{\Theta/T_t} - 1}{e^{\Theta/T} - 1}\right) \left(\frac{T}{T_t}\right)^{\frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1}} \exp\left[\left(\frac{\Theta}{T}\right) \frac{e^{\Theta/T}}{e^{\Theta/T} - 1} - \left(\frac{\Theta}{T_t}\right) \frac{e^{\Theta/T_t}}{e^{\Theta/T_t} - 1}\right] \quad [\text{isen, therm perf}]$$
(189)

The relation between dynamic and static pressure for a thermally imperfect gas can be obtained by a trial-and-error procedure using equations (5), (31a), (183), and (187). The relation between dynamic and static pressure for a thermally perfect gas can be obtained with equations (31b) and (186), and is

$$\frac{q}{p} = \frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1} \left( \frac{T_t}{T} - 1 \right) + \frac{\Theta}{T} \left( \frac{1}{e^{\Theta/T_t} - 1} - \frac{1}{e^{\Theta/T} - 1} \right)$$
[adiab, therm perf] (190)

The variations of 
$$\frac{\left(\frac{p}{p_t}\right)_{\text{therm perf}}}{\left(\frac{p}{p_t}\right)_{\text{perf}}}$$
 and  $\frac{\left(\frac{q}{p_t}\right)_{\text{therm perf}}}{\left(\frac{q}{p_t}\right)_{\text{perf}}}$  with Mach

number for several total temperatures are given in charts 12 and 13.

#### STREAM-TUBE-AREA RELATIONS

The stream-tube-area relation is given by equation (79), or, in more convenient form,

$$\frac{A}{A_*} = \frac{\rho_* a_*}{\rho a M} \tag{191}$$

This ratio can be evaluated for a thermally imperfect gas with the aid of equations (187), (181), (5), and (185), and for a thermally perfect gas with the aid of equations (188),

(182), and (186). The variation of 
$$\frac{\left(\frac{A}{A_*}\right)_{\text{therm perf}}}{\left(\frac{A}{A_*}\right)_{\text{perf}}}$$
 with Mach

number for several values of total temperature is presented in chart 14.

<sup>&</sup>lt;sup>5</sup> In this, as in many of the cases to be presented, no direct solution for flow properties is possible if the gas exhibits both thermal and caloric imperfections. Approximate solutions of this type can be obtained, however, if the degree of imperfection is small (see ref. 7).

#### NORMAL SHOCK WAVES

The requirements for conservation of mass, momentum, and energy across a normal shock wave are given by equations (84), (85), and (86a). The energy relation can be written

$$\begin{split} \frac{u_{2}^{2}}{2} - \frac{u_{1}^{2}}{2} + \frac{R}{\gamma_{\text{pert}} - 1} & (T_{2} - T_{1}) - \left(\frac{2c\,\rho_{2}}{T_{2}} - \frac{2c\,\rho_{1}}{T_{1}}\right) + \left(\frac{p_{2}}{\rho_{2}} - \frac{p_{1}}{\rho_{1}}\right) + \\ & R\Theta\left(\frac{1}{e^{\Theta/T_{2}} - 1} - \frac{1}{e^{\Theta/T_{1}} - 1}\right) = 0 \quad \text{[adiab]} \quad (1\,9\,2) \end{split}$$

or, for a thermally perfect gas,

$$\begin{split} \frac{u_2^2}{2} - \frac{u_1^2}{2} + \left(\frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1}\right) R(T_2 - T_1) + \\ R\Theta\left(\frac{1}{e^{\theta/T_2} - 1} - \frac{1}{e^{\theta/T_1} - 1}\right) = 0 \quad \text{[adiab, therm perf]} \quad (193) \end{split}$$

No explicit equation has been found to relate the temperature downstream of a normal shock wave in thermally imperfect air to the upstream conditions. A trial-and-error procedure, starting with assumed values of  $\rho_2$  and  $T_2$  and involving equations (5), (84), (85), and (192), can be used to determine the downstream temperature.

For the flow of a thermally perfect gas, the simultaneous solution of equations (84), (85), (193), and (2) yields the following relation from which the temperature behind the shock wave can be found:

$$\left(u_{1} + \frac{RT_{1}}{u_{1}}\right)^{2} - \left(u_{1} + \frac{RT_{1}}{u_{1}}\right) \sqrt{\left(u_{1} + \frac{RT_{1}}{u_{1}}\right)^{2} - 4RT_{2}} - 2RT_{2} - 2RT_{2} - 2u_{1}^{2} + \left(\frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}} - 1}\right) 4R(T_{2} - T_{1}) + 4R\Theta\left(\frac{1}{e^{\Theta/T_{2}} - 1} - \frac{1}{e^{\Theta/T_{1}} - 1}\right) = 0 \quad [\text{adiab, therm perf}] \quad (194)$$

Since the total temperature  $T_t$  remains constant across a shock wave, other flow parameters behind the shock wave can be found with the aid of previously presented one-dimensional flow relations. The variations of

$$\frac{\left(\frac{T_2}{T_1}\right)_{\text{therm perf}}}{\left(\frac{T_2}{T_1}\right)_{\text{perf}}}, \frac{\left(\frac{\rho_2}{\rho_1}\right)_{\text{therm perf}}}{\left(\frac{\rho_2}{\rho_1}\right)_{\text{perf}}}, \frac{\left(\frac{p_1}{p_{t_2}}\right)_{\text{therm perf}}}{\left(\frac{p_1}{p_{t_2}}\right)_{\text{perf}}},$$

$$\frac{\left(\frac{p_2}{p_1}\right)_{\text{therm perf}}}{\left(\frac{p_2}{p_1}\right)_{\text{perf}}}, \frac{M_{2_{\text{therm perf}}}}{M_{2_{\text{perf}}}}, \text{ and } \frac{\left(\frac{p_{\iota_2}}{p_{\iota_1}}\right)_{\text{therm perf}}}{\left(\frac{p_{\iota_2}}{p_{\iota_1}}\right)_{\text{perf}}}$$

with upstream Mach number for several total temperatures are presented in charts 15 through 20, respectively.

#### OBLIQUE SHOCK WAVES

For a thermally imperfect gas, no simple equations can be found to relate the values of the flow parameters across oblique shock waves. In general, trial-and-error procedure, starting with assumed values of  $\rho_2$  and  $T_2$ , and involving the relations for the conservation of mass, momentum, and energy, must be used. (See eqs. (115), (116), (117), and (118a) as well as equations (5) and (183).) For a thermally perfect gas, the Mach number downstream of an oblique shock wave can be found with the aid of the energy equation (see eqs. (118a) and (186)), thus

$$\begin{split} M_{2}^{2} &= \frac{2\,T_{1}}{\gamma_{2}T_{2}} \bigg[ \frac{\gamma_{1}M_{1}^{2}}{2} + \bigg( \frac{\gamma_{\text{perf}}}{\gamma_{\text{perf}}-1} \bigg) \bigg( \, 1 - \frac{T_{2}}{T_{1}} \bigg) + \\ & \frac{\Theta}{T_{1}} \bigg( \frac{1}{e^{\Theta/T_{1}}-1} - \frac{1}{e^{\Theta/T_{2}}-1} \bigg) \bigg] \quad [\text{adiab, therm perf}] \quad (1\,9\,5) \end{split}$$

where  $\gamma_1$  and  $\gamma_2$  are the functions of  $T_1$  and  $T_2$ , respectively, given by equation (180). The pressure ratio across the shock is given by

$$\begin{split} \frac{p_{1}}{p_{2}} &= \frac{1}{2} \left\{ (1 + \gamma_{2} M_{2}^{2}) - \frac{T_{1}}{T_{2}} (1 + \gamma_{1} M_{1}^{2}) + \sqrt{\left[ (1 + \gamma_{2} M_{2}^{2}) - \frac{T_{1}}{T_{2}} (1 + \gamma_{1} M_{1}^{2}) \right]^{2} + 4 \frac{T_{1}}{T_{2}}} \right\} \\ & \quad [adiab, therm perf] \quad (196) \end{split}$$

The density ratio can be determined from the equation of state (eq. (2)) with the aid of the pressure and temperature ratios. The shock-wave and deflection angles are given by (see ref. 8)

$$\sin^2 \theta = \frac{\left(\frac{\gamma_2}{\gamma_1}\right) \left(\frac{T_2}{T_1}\right) \left(\frac{M_2}{M_1}\right)^2 - 1}{\left(\frac{\rho_1}{\rho_2}\right)^2 - 1} \quad \text{[adiab, therm perf]} \quad (197)$$

and

$$\cot \delta = \tan \theta \left( \frac{\gamma_1 M_1^2}{\frac{p_2}{p_1} - 1} \right) \quad [adiab, therm perf] \quad (198)$$

respectively

The variation of  $\theta$  with  $\delta$  for various values of  $M_1$  and  $T_1$  is presented in chart 21. In addition, the variations of

$$\frac{(M_2)_{\texttt{therm perf}}}{(M_2)_{\texttt{perf}}} \text{ and } \frac{\left(\frac{p_2 - p_1}{q_1}\right)_{\texttt{therm perf}}}{\left(\frac{p_2 - p_1}{q_1}\right)_{\texttt{perf}}} \text{ with } \delta \text{ for various } M_1 \text{ and } T_1$$

are presented in charts 22 and 23.

Values of the ratios

$$\frac{p_2}{p_1}, \frac{
ho_2}{
ho_1}, \frac{T_2}{T_1}, \frac{p_{t_2}}{p_{t_1}}$$

for the flow of a thermally perfect gas across an oblique shock wave can be determined from the normal-shock relations,

provided that  $M_1 \sin \theta$  is used instead of  $M_1$  and that the static temperature  $T_1$  just upstream of the shock wave is the same for the oblique shock wave as for the normal shock wave.

#### PRANDTL-MEYER EXPANSION

The Prandtl-Meyer angle for the flow of an imperfect gas can be found by graphically integrating the equation (see ref. 8)

$$\nu = -\int_{v_*}^{v} \frac{dp}{\rho V^2 \tan \mu} \quad \text{[isen]}$$

The relations between p,  $\rho$ , V, and  $\mu$  can be found with the

aid of equations (5), (187), (183), and (185). For a thermally perfect gas this equation becomes (see, again, ref. 8)

$$\nu = -\int_{p_*}^{p} \frac{\sin 2\mu}{2\gamma p} dp \quad \text{[isen, therm perf]} \tag{200}$$

The relations between  $\gamma$ , p, and  $\mu$  can be found with the aid of equations (180), (189), and (186) using the temperature as a parameter. The graphical integration of equation (200) has been carried out, and the variations of  $\nu_{\text{therm perf}}$  and  $\frac{\nu_{\text{therm perf}}}{\nu_{\text{perf}}}$  with Mach number for various values of total temperature are presented in chart 24.

#### APPENDIX A

#### VISCOSITY AND THERMODYNAMIC CONSTANTS FOR AIR

#### VISCOSITY

The viscosity of air is nearly independent of pressure; the variation with absolute temperature, between temperatures of about 300° R and 900° R, may be approximated by the formula

$$\frac{\mu}{\mu_r} = \left(\frac{T}{T_r}\right)^{0.76} \tag{A1}$$

For a wider range of temperatures, between about  $180^{\circ}$  R and  $3400^{\circ}$  R, Sutherland's formula (see ref. 19) is more accurate:

$$\frac{\mu}{\mu_r} = \frac{T_r + 198.6}{T + 198.6} \left(\frac{T}{T_r}\right)^{3/2} \tag{A2}$$

The viscosity of air, as determined from this relation, may be expressed as

$$\mu = 2.270 \frac{T^{3/2}}{T + 198.6} \times 10^{-8} \frac{\text{lb sec}}{\text{ft}^2}$$
 (A3)

This latter equation has been employed in the calculations of Reynolds number (chart 25).

#### THERMODYNAMIC CONSTANTS

The value of  $\gamma$  employed for air, when treated as a completely perfect gas, is 7/5. This simple value, which has been employed in table I, table II, charts 1 to 4, and chart 25, is a good approximation to the more precise values obtained from spectroscopic measurements (see ref. 20). Values of  $c_p$ ,  $c_v$ , and R for air, consistent with the approximation  $\gamma = 7/5$ , are

$$c_p = 6006 \text{ ft}^2/\text{sec}^2 \text{ }^2\text{R}$$
  
 $c_v = 4290 \text{ ft}^2/\text{sec}^2 \text{ }^2\text{R}$   
 $R = 1716 \text{ ft}^2/\text{sec}^2 \text{ }^2\text{R}$ 

#### APPENDIX B

#### REYNOLDS NUMBER

Revnolds number is defined as

$$R = \frac{\rho V l}{\mu} \tag{B1}$$

For sea-level conditions,

$$R \simeq 10.000 \ (V \text{ in mph}) \ (l \text{ in ft})$$
 (B2)

In a wind tunnel (subsonic or supersonic), if isentropic expansion is assumed from a total pressure  $p_t$  and equation

(A2) is used for the variation of viscosity with temperature, the Reynolds number per unit reference length is given by

$$\frac{R}{l} = \frac{p_t M}{\mu_t} \sqrt{\frac{\gamma}{(\gamma - 1)c_v T_t}} \left(\frac{T_t}{T}\right)^{\frac{\gamma - 2}{\gamma - 1}} \frac{T_t}{T_t} + \frac{198.6}{T_t} \quad \text{[perf]} \quad \text{(B3)}$$

The Reynolds number per unit length for  $p_t=1$  psia has been plotted in chart 25 as a function of M for various total temperatures  $T_t$ .

#### APPENDIX C

#### PRESSURE CONVERSION FACTORS AND CONSTANTS

Multiply——— by to obtain	lb in.²	$rac{ ext{lb}}{ ext{ft}^2}$	in. H <sub>2</sub> O at 70° F	in. Hg at 70° F	em. Hg at 70° F	Standard atmos- pheres
lb/in.² lb/ft² in. H <sub>2</sub> O (70° F) in. Hg. (70° F) em. Hg. (70° F) Standard atmospheres	1 144 27. 73 2. 044 5. 192 . 06804	0. 006944 1 1 . 1925 . 01420 . 03605 . 0004725	0. 03607 5. 194 1 . 07373 . 1873 . 002453	0. 4892 70. 45 13. 56 1 2. 540	0. 1926 27. 74 5. 340 . 3937 1	14. 70 2117 407. 6 30. 05 76. 33

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#### **TABLES**

The tables that follow contain numerical values for certain quantities often required for the solution of problems in compressible flow. The symbols used in these tables are the same as those used in the preceding sections. For convenience, however, the symbols are redefined at the end of table II.

To conserve space, a modified computing-machine notation has been adopted to indicate the position of the decimal point in the tabulated quantities. The location of the decimal point is governed by the following rules:

(a) A group of digits followed by \_n indicates that the decimal point should be n places to the left of the first digit.

Example:  $.3268_{-3} = .0003268$ 

(b) A group of digits followed by +n indicates that the decimal point should be n places to the right of the last digit.

Example:  $3268_{+3} = 3,268,000$ 

(c) A group of digits without a suffix indicates that the decimal point is correctly located as printed.

#### TABLE I.—SUBSONIC FLOW

The ratios given by equations (43), (44), (45), (48), (50), and (83) are given as functions of Mach number. If, at a point in an isentropic flow, any one of these ratios or the Mach number is known, then all other ratios for that point can be read or interpolated from the table. In addition, the parameter  $\beta = \sqrt{|M^2 - 1|}$ , which is sometimes more convenient to use than the Mach number itself, is also tabulated.

#### TABLE II.—SUPERSONIC FLOW

The ratios given in table I for subsonic flow are also given in table II for supersonic flow. The Mach angle  $\mu$  and the Prandtl-Meyer angle  $\nu$  are also given as functions of Mach number. In addition to these point functions for isentropic flow, the normal-shock relations given by equations (93), (94), (95), (96), (99), and (100) are tabulated as functions of the Mach number  $M_1$  ahead of the shock wave. Although these values are for normal shock waves, the values of  $p_2/p_1$ ,  $p_2/\rho_1$ ,  $T_2/T_1$ , and  $p_{t_2}/p_{t_1}$  may also be used for oblique shock waves, provided  $M_1$  sin  $\theta$  is used instead of  $M_1$  in the first column.

#### EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

#### TABLE I.—SUBSONIC FLOW

 $\gamma = 7/5$ 

M	$\frac{p}{p_t}$	$\frac{\rho}{\rho_t}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_{\bullet}}$	$\frac{V}{a_*}$	M d	$\frac{p}{p_t}$	$\frac{\rho}{\rho_t}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_{\bullet}}$	$\frac{V}{a_*}$
0 . 01 . 02 . 03 . 04	1.0000 .9999 .9997 .9994 .9989	1,0000 1,0000 ,9998 ,9996 ,9992	1.0000 1.0000 .9999 .9998 .9997	1. 0000 1. 0000 . 9998 . 9995 . 9992	0 .7000 -4 .2799 -3 .6296 -3 .1119 -2	57. 8738 28. 9421 19. 3005 14. 4815	0 . 01095 . 02191 . 03286 . 04381	0. 50 . 51 . 52 . 53 . 54	0. 8430 . 8374 . 8317 . 8259 . 8201	0. 8852 . 8809 . 8766 . 8723 . 8679	0. 9524 . 9506 . 9487 . 9468 . 9449	0. 8660 . 8602 . 8542 . 8480 . 8417	0. 1475 . 1525 . 1574 . 1624 . 1674	1. 3398 1. 3212 1. 3034 1. 2865 1. 2703	0. 53452 . 54469 . 55483 . 56493 . 57501
. 05	. 9983	. 9988	. 9995	. 9987	$\begin{array}{cccc} .\ 1747 & -2 \\ .\ 2514 & -2 \\ .\ 3418 & -2 \\ .\ 4460 & -2 \\ .\ 5638 & -2 \\ \end{array}$	11, 5914	. 05476	. 55	. 8142	. 8634	. 9430	. 8352	. 1724	1. 2550	. 58506
. 06	. 9975	. 9982	. 5993	. 9982		9, 6659	. 06570	. 56	. 8082	. 8589	. 9410	. 8285	. 1774	1. 2403	. 59507
. 07	. 9966	. 9976	. 9990	. 9975		8, 2915	. 07664	. 57	. 8022	. 8544	. 9390	. 8216	. 1825	1. 2263	. 60505
. 08	. 9955	. 9968	. 9987	. 9968		7, 2616	. 08758	. 58	. 7962	. 8498	. 9370	. 8146	. 1875	1. 2130	. 61501
. 09	. 9944	. 9960	. 9984	. 9959		6, 4613	. 09851	. 59	. 7901	. 8451	. 9349	. 8074	. 1925	1. 2003	. 62492
. 10	. 9930	. 9950	. 9980	. 9950	$\begin{array}{cccc} .6951 & -2 \\ .8399 & -2 \\ .9979 & -2 \\ .1169 & -1 \\ .1353 & -1 \\ \end{array}$	5. 8218	. 10944	. 60	. 7840	. 8405	. 9328	. 8000	. 1976	1. 1882	. 63481
. 11	. 9916	. 9940	. 9976	. 9939		5. 2992	. 12035	. 61	. 7778	. 8357	. 9307	. 7924	. 2026	1. 1767	. 64466
. 12	. 9900	. 9928	. 9971	. 9928		4. 8643	. 13126	. 62	. 7716	. 8310	. 9286	. 7846	. 2076	1. 1657	. 65448
. 13	. 9883	. 9916	. 9966	. 9915		4. 4969	. 14217	. 63	. 7654	. 8262	. 9265	. 7766	. 2127	1. 1552	. 66427
. 14	. 9864	. 9903	. 9961	. 9902		4. 1824	. 15306	. 64	. 7591	. 8213	. 9243	. 7684	. 2177	1. 1452	. 67402
. 15	. 9344	. 9888	. 9955	. 9887	. 1550 -1	3. 9103	. 16395	. 65	. 7528	. 8164	. 9221	. 7599	. 2227	1. 1356	. 68374
. 16	. 9823	. 9873	. 9949	. 9871	. 1760 -1	3. 6727	. 17482	. 66	. 7465	. 8115	. 9199	. 7513	. 2276	1. 1265	. 69342
. 17	. 9800	. 9857	. 9943	. 9854	. 1983 -1	3. 4635	. 18569	. 67	. 7401	. 8066	. 9176	. 7424	. 2326	1. 1179	. 70307
. 18	. 9776	. 9840	. 9936	. 9837	. 2217 -1	3. 2779	. 19654	. 68	. 7338	. 8016	. 9153	. 7332	. 2375	1. 1097	. 71263
. 19	. 9751	. 9822	. 9928	. 9818	. 2464 -1	3. 1123	. 20739	. 69	. 7274	. 7966	. 9131	. 7238	. 2424	1. 1018	. 72225
. 20	. 9725	. 9803	. 9921	. 9798	. 2723 -1	2. 9635	. 21822	. 70	. 7209	. 7916	. 9107	. 7141	. 2473	1. 0944	. 73179
. 21	. 9697	. 9783	. 9913	. 9777	. 2994 -1	2. 8293	. 22904	. 71	. 7145	. 7865	. 9084	. 7042	. 2521	1. 0873	. 74129
. 22	. 9668	. 9762	. 9904	. 9755	. 3276 -1	2. 7076	. 23984	. 72	. 7080	. 7814	. 9061	. 6940	. 2569	1. 0806	. 75076
. 23	. 9638	. 9740	. 9895	. 9732	. 3569 -1	2. 5968	. 25063	. 73	. 7016	. 7763	. 9037	. 6834	. 2617	1. 0742	. 7€019
. 24	. 9607	. 9718	. 9886	. 9708	. 3874 -1	2. 4956	. 26141	. 74	. 6951	. 7712	. 9013	. 6726	. 2664	1. 0681	. 76958
. 25	. 9575	. 9694	. 9877	. 9682	.4189 -1	2. 4027	. 27217	. 75	. 6886	. 7660	. 8989	. 6614	. 2711	1. 0624	. 77894
. 26	. 9541	. 9670	. 9867	. 9656	.4515 -1	2. 3173	. 28291	. 76	. 6821	. 7609	. 8964	. 6499	. 2758	1. 0570	. 78825
. 27	. 9506	. 9645	. 9856	. 9629	.4851 -1	2. 2385	. 29364	. 77	. 6756	. 7557	. 8940	. 6380	. 2804	1. 0519	. 79753
. 28	. 9470	. 9619	. 9846	. 9600	.5197 -1	2. 1656	. 30435	. 78	. 6691	. 7505	. 8915	. 6258	. 2849	1. 0471	. 80677
. 29	. 9433	. 9592	. 9335	. 9570	.5553 -1	2. 0979	. 31504	. 79	. 6625	. 7452	. 8890	. 6131	. 2894	1. 0425	. 81597
.30	. 9395	. 9564	. 9823	. 9539	. 5919 -1	2. 0351	.32572	. 80	. 6560	. 7400	. 8865	. 6000	. 2939	1. 0382	. 82514
.31	. 9355	. 9535	. 9811	. 9507	. 6293 -1	1. 9765	.33637	. 81	. 6495	. 7347	. 8840	. 5864	. 2983	1. 0342	. 83426
.32	. 9315	. 9506	. 9799	. 9474	. 6677 -1	1. 9219	.34701	. 82	. 6430	. 7295	. 8815	. 5724	. 3027	1. 0305	. 84335
.33	. 9274	. 9476	. 9787	. 9440	. 7069 -1	1. 8707	.35762	. 83	. 6365	. 7242	. 8789	. 5578	. 3069	1. 0270	. 85239
.34	. 9231	. 9445	. 9774	. 9404	. 7470 -1	1. 8229	.36822	. 84	. 6300	. 7189	. 8763	. 5426	. 3112	1. 0237	. 86140
.35	. 9188	. 9413	. 9761	. 9367	. 7879 -1	1. 7780	.37879	. 85	. 6235	. 7136	. 8737	. 5268	.3153	1. 0207	. 87037
.36	. 9143	. 9380	. 9747	. 9330	. 8295 -1	1. 7358	.38935	. 86	. 6170	. 7083	. 8711	. 5103	.3195	1. 0179	. 87929
.37	. 9098	. 9347	. 9733	. 9290	. 8719 -1	1. 6961	.39988	. 87	. 6106	. 7030	. 8685	. 4931	.3235	1. 0153	. 88818
.38	. 9052	. 9313	. 9719	. 9250	. 9149 -1	1. 6587	.41039	. 88	. 6041	. 6977	. 8659	. 4750	.3275	1. 0129	. 89703
.39	. 9004	. 9278	. 9705	. 9208	. 9587 -1	1. 6234	.42087	. 89	. 5977	. 6924	. 8632	. 4560	.3314	1. 0108	. 90583
. 40	. 8956	. 9243	. 9690	. 9165	. 1003	1. 5901	. 43133	. 90	. 5913	. 6870	. 8606	. 4359	. 3352	1. 0089	. 91460
. 41	. 8907	. 9207	. 9675	. 9121	. 1048	1. 5587	. 44177	. 91	. 5849	. 6817	. 8579	. 4146	. 3390	1. 0071	. 92332
. 42	. 8857	. 9170	. 9659	. 9075	. 1094	1. 5289	. 45218	. 92	. 5785	. 6764	. 8552	. 3919	. 3427	1. 0056	. 93201
. 43	. 8807	. 9132	. 9643	. 9028	. 1140	1. 5007	. 46257	. 93	. 5721	. 6711	. 8525	. 3676	. 3464	1. 0043	. 94065
. 44	. 8755	. 9094	. 9627	. 8980	. 1187	1. 4740	. 47293	. 94	. 5658	. 6658	. 8498	. 3412	. 3500	1. 0031	. 94925
. 45	. 8703	. 9055	. 9611	. 8930	. 1234	1. 4487	. 48326	. 95	. 5595	. 6604	. 8471	.3122	.3534	1. 0022	. 95781
. 46	. 8650	. 9016	. 9594	. 8879	. 1281	1. 4246	. 49357	. 96	. 5532	. 6551	. 8444	.2800	.3569	1. 0014	. 96633
. 47	. 8596	. 8976	. 9577	. 8827	. 1329	1. 4018	. 50385	. 97	. 5469	. 6498	. 8416	.2431	.3602	1. 0008	. 97481
. 48	. 8541	. 8935	. 9560	. 8773	. 1378	1. 3801	. 51410	. 98	. 5407	. 6445	. 8389	.1990	.3635	1. 0003	. 93325
. 49	. 8486	. 8894	. 9542	. 8717	. 1426	1. 3595	. 52433	. 99	. 5345	. 6392	. 8361	.1411	.3667	1. 0001	. 99165
								1.00	. 5283	. 6339	. 8333	. 0000	. 3698	1. 0000	1, 00000

#### TABLE II.—SUPERSONIC FLOW

$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho_t}$	$\frac{T}{T_t}$	β	$rac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$\frac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
1.00 1.01 1.02 1.03 1.04	0. 5283 . 5221 . 5160 . 5099 . 5039	0. 6339 . 6287 . 6234 . 6181 . 6129	0. 8333 . 8306 . 8278 . 8250 . 8222	0 . 1418 . 2010 . 2468 . 2857	0. 3698 . 3728 . 3758 . 3787 . 3815	1. 000 1. 000 1. 000 1. 001 1. 001	1, 00000 1, 00831 1, 01658 1, 02481 1, 03300	0 . 04473 . 1257 . 2294 . 3510	90. 00 81, 93 78, 64 76, 14 74, 06	1.000 .9901 .9805 .9712 .9620	1. 000 1. 023 1. 047 1. 071 1. 095	1, 000 1, 017 1, 033 1, 050 1, 067	1. 000 1. 007 1. 013 1. 020 1. 026	1,000 1,000 1,000 1,000 1,000 ,9999	0. 5283 . 5221 . 5160 . 5100 . 5039
1. 05	. 4979	. 6077	. 8193	.3202	.3842	1. 002	1. 04114	. 4874	72. 25	. 9531	1. 120	1. 084	1. 033	.9999	. 4980
1. 06	. 4919	. 6024	. 8165	.3516	.3869	1. 003	1. 04925	. 6367	70. 63	. 9444	1. 144	1. 101	1. 039	.9997	. 4920
1. 07	. 4860	. 5972	. 8137	.3807	.3895	1. 004	1. 05731	. 7973	69. 16	. 9360	1. 169	1. 118	1. 046	.9996	. 4861
1. 08	. 4800	. 5920	. 8108	.4079	.3919	1. 005	1. 06533	. 9680	67. 81	. 9277	1. 194	1. 135	1. 052	.9994	. 4803
1. 09	. 4742	. 5869	. 8080	.4337	.3944	1. 006	1. 07331	1. 148	66. 55	. 9196	1. 219	1. 152	1. 059	.9992	. 4746
1. 10	. 4684	. 5817	. 8052	. 4583	. 3967	1. 008	1. 08124	1. 336	65. 38	. 9118	1. 245	1. 169	1. 065	. 9989	. 4689
1. 11	. 4626	. 5766	. 8023	. 4818	. 3990	1. 010	1. 08913	1. 532	64. 28	. 9041	1. 271	1. 186	1. 071	. 9986	. 4632
1. 12	. 4568	. 5714	. 7994	. 5044	. 4011	1. 011	1. 09699	1. 735	63. 23	. 8966	1. 297	1. 203	1. 078	. 9982	. 4576
1. 13	. 4511	. 5663	. 7966	. 5262	. 4032	1. 013	1. 10479	1. 944	62. 25	. 8892	1. 323	1. 221	1. 084	. 9978	. 4521
1. 14	. 4455	. 5612	. 7937	. 5474	. 4052	1. 015	1. 11256	2. 160	61. 31	. 8820	1. 350	1. 238	1. 090	. 9973	. 4467
1. 15	. 4398	. 5562	.7908	. 5679	. 4072	1. 017	1. 12029	2. 381	60. 41.	. 8750	1. 376	1, 255	1. 097	. 9967	. 4413
1. 16	. 4343	. 5511	.7879	. 5879	. 4090	1. 020	1. 12797	2. 607	59. 55	. 8682	1. 403	1, 272	1. 103	. 9961	. 4360
1. 17	. 4287	. 5461	.7851	. 6074	. 4108	1. 022	1. 13561	2. 839	58. 73	. 8615	1. 430	1, 290	1. 109	. 9953	. 4307
1. 18	. 4232	. 5411	.7822	. 6264	. 4125	1. 025	1. 14321	3. 074	57. 94	. 8549	1. 458	1, 307	1. 115	. 9946	. 4255
1. 19	. 4178	. 5361	.7793	. 6451	. 4141	1. 026	1. 15077	3. 314	57. 18	. 8485	1. 485	1, 324	1. 122	. 9937	. 4204
1. 20	. 4124	. 5311	. 7764	. 6633	. 4157	1. 030	1. 15828	3. 558	56. 44	. 8422	1. 513	1. 342	1. 128	. 9928	. 4154
1. 21	. 4070	. 5262	. 7735	. 6812	. 4171	1. 033	1. 16575	3. 806	55. 74	. 8360	1. 541	1. 359	1. 134	. 9918	. 4104
1. 22	. 4017	. 5213	. 7706	. 6989	. 4185	1. 037	1. 17319	4. 057	55. 05	. 8300	1. 570	1. 376	1. 141	. 9907	. 4055
1. 23	. 3964	. 5164	. 7677	. 7162	. 4198	1. 040	1. 18057	4. 312	54. 39	. 8241	1. 598	1. 394	1. 147	. 9896	. 4006
1. 24	. 3912	. 5115	. 7648	. 7332	. 4211	1. 043	1. 18792	4. 569	53. 75	. 8183	1. 627	1. 411	1. 153	. 9884	. 3958

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#### TABLE II.—SUPERSONIC FLOW—Continued

							$\gamma = 7/5$								
$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho \iota}$	$rac{T}{T_t}$	β	$rac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	M <sub>2</sub>	$rac{oldsymbol{p_2}}{oldsymbol{p_1}}$	<u>ρ2</u> ρ1	$\frac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{\boldsymbol{p}_{t_2}}$
1. 25	. 3861	. 5067	. 7619	. 7500	. 4223	1. 047	1. 19523	4. 830	53. 13	. 8126	1. 656	1. 429	1. 159	. 9871	. 3911
1. 26	. 3809	. 5019	. 7590	. 7666	. 4233	1. 050	1. 20249	5. 093	52. 53	. 8071	1. 686	1. 446	1. 166	. 9857	. 3865
1. 27	. 3759	. 4971	. 7561	. 7829	. 4244	1. 054	1. 20972	5. 359	51. 94	. 8016	1. 715	1. 463	1. 172	. 9842	. 3819
1. 28	. 3708	. 4923	. 7532	. 7990	. 4253	1. 058	1. 21690	5. 627	51. 38	. 7963	1. 745	1. 481	1. 178	. 9827	. 3774
1. 29	. 3658	. 4876	. 7503	. 8149	. 4262	1. 062	1. 22404	5. 898	50. 82	. 7911	1. 775	1. 498	1. 185	. 9811	. 3729
1. 30	.3609	. 4829	. 7474	. 8307	. 4270	1. 066	1. 23114	6. 170	50. 28	. 7860	1. 805	1. 516	1. 191	. 9794	.3685
1. 31	.3560	. 4782	. 7445	. 8462	. 4277	1. 071	1. 23819	6. 445	49. 76	. 7809	1. 835	1. 533	1. 197	. 9776	.3642
1. 32	.3512	. 4736	. 7416	. 8616	. 4283	1. 075	1. 24521	6. 721	49. 25	. 7760	1. 866	1. 551	1. 204	. 9758	.3599
1. 33	.3464	. 4690	. 7387	. 8769	. 4289	1. 080	1. 25218	7. 000	48. 75	. 7712	1. 897	1. 568	1. 210	. 9738	.3557
1. 34	.3417	. 4644	. 7358	. 8920	. 4294	1. 084	1. 25912	7. 280	48. 27	. 7664	1. 928	1. 585	1. 216	. 9718	.3516
1. 35	.3370	. 4598	. 7329	. 9069	. 4299	1. 089	1. 26601	7. 561	47. 79	. 7618	1. 960	1. 603	1, 223	. 9697	.3475
1. 36	.3323	. 4553	. 7300	. 9217	. 4303	1. 094	1. 27286	7. 844	47. 33	. 7572	1. 991	1. 620	1, 229	. 9676	.3435
1. 37	.3277	. 4508	. 7271	. 9364	. 4306	1. 099	1. 27968	8. 128	46. 88	. 7527	2. 023	1. 638	1, 235	. 9653	.3395
1. 38	.3232	. 4463	. 7242	. 9510	. 4308	1. 104	1. 28645	8. 413	46. 44	. 7483	2. 055	1. 655	1, 242	. 9630	.3356
1. 39	.3187	. 4418	. 7213	. 9655	. 4310	1. 109	1. 29318	8. 699	46. 01	. 7440	2. 087	1. 672	1, 248	. 9607	.3317
1. 40	.3142	. 4374	.7184	. 9798	.4311	1. 115	1. 29987	8. 987	45. 58	. 7397	2. 120	1, 690	1. 255	. 9582	.3280
1. 41	.3098	. 4330	.7155	. 9940	.4312	1. 120	1. 30652	9. 276	45. 17	. 7355	2. 153	1, 707	1. 261	. 9557	.3242
1. 42	.3055	. 4287	.7126	1. 008	.4312	1. 126	1. 31313	9. 565	44. 77	. 7314	2. 186	1, 724	1. 268	. 9531	.3205
1. 43	.3012	. 4244	.7097	1. 022	.4311	1. 132	1. 31970	9. 855	44. 37	. 7274	2. 219	1, 742	1. 274	. 9504	.3169
1. 44	.2969	. 4201	.7069	1. 036	.4310	1. 138	1. 32623	10. 146	43. 98	. 7235	2. 253	1, 759	1. 281	. 9476	.3133
1. 45	. 2927	. 4158	.7040	1, 050	. 4308	1. 144	1, 33272	10. 438	43. 60	.7196	2. 286	1, 776	1. 287	. 9448	.3098
1. 46	. 2886	. 4116	.7011	1, 064	. 4306	1. 150	1, 33917	10. 731	43. 23	.7157	2. 320	1, 793	1. 294	. 9420	.3063
1. 47	. 2845	. 4074	.6982	1, 077	. 4303	1. 156	1, 34558	11. 023	42. 86	.7120	2. 354	1, 811	1. 300	. 9390	.3029
1. 48	. 2804	. 4032	.6954	1, 091	. 4299	1. 163	1, 35195	11. 317	42. 51	.7083	2. 389	1, 828	1. 307	. 9360	.2996
1. 49	. 2764	. 3991	.6925	1, 105	. 4295	1. 169	1, 35828	11. 611	42. 16	.7047	2. 423	1, 845	1. 314	. 9329	.2962
1. 50	. 2724	. 3950	. 6897	1, 118	. 4290	1. 176	1, 36458	11. 905	41. 81	. 7011	2, 458	1, 862	1. 320	. 9298	. 2930
1. 51	. 2685	. 3909	. 6868	1, 131	. 4285	1. 183	1, 37083	12. 200	41. 47	. 6976	2, 493	1, 879	1. 327	. 9266	. 2898
1. 52	. 2646	. 3869	. 6840	1, 145	. 4279	1. 190	1, 37705	12. 495	41. 14	. 6941	2, 529	1, 896	1. 334	. 9233	. 2866
1. 53	. 2608	. 3829	. 6811	1, 158	. 4273	1. 197	1, 38322	12. 790	40. 81	. 6907	2, 564	1, 913	1. 340	. 9200	. 2835
1. 54	. 2570	. 3789	. 6783	1, 171	. 4266	1. 204	1, 38936	13. 086	40. 49	. 6874	2, 600	1, 930	1. 347	. 9166	. 2804
1, 55	. 2533	. 3750	. 6754	1, 184	. 4259	1. 212	1. 39546	13. 381	40. 18	. 6841	2, 636	1, 947	1, 354	. 9132	. 2773
1, 56	. 2496	. 3710	. 6726	1, 197	. 4252	1. 219	1. 40152	13. 677	39. 87	. 6809	2, 673	1, 964	1, 361	. 9097	. 2744
1, 57	. 2459	. 3672	. 6698	1, 210	. 4243	1. 227	1. 40755	13. 973	39. 56	. 6777	2, 709	1, 981	1, 367	. 9061	. 2714
1, 58	. 2423	. 3633	. 6670	1, 223	. 4235	1. 234	1. 41353	14. 269	39. 27	. 6746	2, 746	1, 998	1, 374	. 9026	. 2685
1, 59	. 2388	. 3595	. 6642	1, 236	. 4226	1. 242	1. 41948	14. 564	38. 97	. 6715	2, 783	2, 015	1, 381	. 8989	. 2656
1. 60	. 2353	.3557	. 6614	1, 249	. 4216	1, 250	1. 42539	14.861	38, 68	. 6684	2, 820	2. 032	1, 388	. 8952	. 2628
1. 61	. 2318	.3520	. 6586	1, 262	. 4206	1, 258	1. 43127	15.156	38, 40	. 6655	2, 857	2. 049	1, 395	. 8915	. 2600
1. 62	. 2284	.3483	. 6558	1, 275	. 4196	1, 267	1. 43710	15.452	38, 12	. 6625	2, 895	2. 065	1, 402	. 8877	. 2573
1. 63	. 2250	.3446	. 6530	1, 287	. 4185	1, 275	1. 44290	15.747	37, 84	. 6596	2, 933	2. 082	1, 409	. 8838	. 2546
1. 64	. 2217	.3409	. 6502	1, 300	. 4174	1, 284	1. 44866	16.043	37, 57	. 6568	2, 971	2. 099	1, 416	. 8799	. 2519
1, 65	.2184	.3373	. 6475	1.312	.4162	1, 292	1. 45439	16. 338	37. 31	. 6540	3. 010	2. 115	1. 423	. 8760	. 2493
1, 66	.2151	.3337	. 6447	1.325	.4150	1, 301	1. 46008	16. 633	37. 04	. 6512	3. 048	2. 132	1. 430	. 8720	. 2467
1, 67	.2119	.3302	. 6419	1.337	.4138	1, 310	1. 46573	16. 928	36. 78	. 6485	3. 087	2. 148	1. 437	. 8680	. 2442
1, 68	.2088	.3266	. 6392	1.350	.4125	1, 319	1. 47135	17. 222	36. 53	. 6458	3. 126	2. 165	1. 444	. 8640	. 2417
1, 69	.2057	.3232	. 6364	1.362	.4112	1, 328	1. 47693	17. 516	36. 28	. 6431	3. 165	2. 181	1. 451	. 8598	. 2392
1. 70	. 2026	.3197	. 6337	1, 375	. 4098	1. 338	1. 48247	17. 810	36. 03	. 6405	3. 205	2. 198	1, 458	. 8557	. 2368
1. 71	. 1996	.3163	. 6310	1, 387	. 4085	1. 347	1. 48798	18. 103	35. 79	. 6380	3. 245	2. 214	1, 466	. 8516	. 2344
1. 72	. 1966	.3129	. 6283	1, 399	. 4071	1. 357	1. 49345	18. 397	35. 55	. 6355	3. 285	2. 230	1, 473	. 8474	. 2320
1. 73	. 1936	.3095	. 6256	1, 412	. 4056	1. 367	1. 49889	18. 689	35. 31	. 6330	3. 325	2. 247	1, 480	. 8431	. 2296
1. 74	. 1907	.3062	. 6229	1, 424	. 4041	1. 376	1. 50429	18. 981	35. 08	. 6305	3. 366	2. 263	1, 487	. 8389	. 2273
1. 75	.1878	. 3029	.6202	1. 436	. 4026	1, 386	1,50966	19, 273	34. 85	. 6281	3. 406	2. 279	1, 495	. 8346	. 2251
1. 76	.1850	. 2996	.6175	1. 448	. 4011	1, 397	1,51499	19, 565	34. 62	. 6257	3. 447	2. 295	1, 502	. 8302	. 2228
1. 77	.1822	. 2964	.6148	1. 460	. 3996	1, 407	1,52029	19, 855	34. 40	. 6234	3. 488	2. 311	1, 509	. 8259	. 2206
1. 78	.1794	. 2931	.6121	1. 473	. 3980	1, 418	1,52555	20, 146	34. 18	. 6210	3. 530	2. 327	1, 517	. 8215	. 2184
1. 79	.1767	. 2900	.6095	1. 485	. 3964	1, 428	1,53078	20, 436	33. 96	. 6188	3. 571	2. 343	1, 524	. 8171	. 2163
1.80	. 1740	. 2868	. 6068	1. 497	. 3947	1, 439	1.53598	20. 725	33. 75	. 6165	3. 613	2. 359	1, 532	. 8127	. 2142
1.81	. 1714	. 2837	. 6041	1. 509	. 3931	1, 450	1.54114	21. 014	33. 54	. 6143	3. 655	2. 375	1, 539	. 8082	. 2121
1.82	. 1688	. 2806	. 6015	1. 521	. 3914	1, 461	1.54626	21. 302	33. 33	. 6121	3. 698	2. 391	1, 547	. 8038	. 2100
1.83	. 1662	. 2776	. 5989	1. 533	. 3897	1, 472	1.55136	21. 590	33. 12	. 6099	3. 740	2. 407	1, 554	. 7993	. 2080
1.84	. 1637	. 2745	. 5963	1. 545	. 3879	1, 484	1.55642	21. 877	32. 92	. 6078	3. 783	2. 422	1, 562	. 7948	. 2060
1.85	. 1612	. 2715	. 5936	1, 556	. 3862	1. 495	1. 56145	22. 163	32. 72	. 6057	3. 826	2. 438	1, 569	. 7902	. 2040
1.86	. 1587	. 2686	. 5910	1, 568	. 3844	1. 507	1. 56644	22. 449	32. 52	. 6036	3. 870	2. 454	1, 577	. 7857	. 2020
1.87	. 1563	. 2656	. 5884	1, 580	. 3826	1. 519	1. 57140	22. 735	32. 33	. 6016	3. 913	2. 469	1, 585	. 7811	. 2001
1.88	. 1539	. 2627	. 5859	1, 592	. 3808	1. 531	1. 57633	23. 019	32. 13	. 5996	3. 957	2. 485	1, 592	. 7765	. 1982
1.89	. 1516	. 2598	. 5833	1, 604	. 3790	1. 543	1. 58123	23. 303	31. 94	. 5976	4. 001	2. 500	1, 600	. 7720	. 1963
1. 90	. 1492	. 2570	. 5807	1. 616	.3771	1. 555	1. 58609	23. 586	31. 76	. 5956	4. 045	2. 516	1, 608	. 7674	. 1945
1. 91	. 1470	. 2542	. 5782	1. 627	.3753	1. 568	1. 59092	23. 869	31. 57	. 5937	4. 089	2. 531	1, 616	. 7627	. 1927
1. 92	. 1447	. 2514	. 5756	1. 639	.3734	1. 580	1. 59572	24. 151	31. 39	. 5918	4. 134	2. 546	1, 624	. 7581	. 1909
1. 93	. 1425	. 2486	. 5731	1. 651	.3715	1. 593	1. 60049	24. 432	31. 21	. 5899	4. 179	2. 562	1, 631	. 7535	. 1891
1. 94	. 1403	. 2459	. 5705	1. 662	.3696	1. 606	1. 60523	24. 712	31. 03	. 5880	4. 224	2. 577	1, 639	. 7488	. 1873
1. 95	. 1381	. 2432	. 5680	1. 674	.3677	1. 619	1. 60993	24. 992	30. 85	. 5862	4. 270	2. 592	1, 647	. 7442	. 1856
1. 96	. 1360	. 2405	. 5655	1. 686	.3657	1. 633	1. 61460	25. 271	30. 68	. 5844	4. 315	2. 607	1, 655	. 7395	. 1839
1. 97	. 1339	. 2378	. 5630	1. 697	.3638	1. 646	1. 61925	25. 549	30. 51	. 5826	4. 361	2. 622	1, 663	. 7349	. 1822
1. 98	. 1318	. 2352	. 5605	1. 709	.3618	1. 660	1. 62386	25. 827	30. 33	. 5808	4. 407	2. 637	1, 671	. 7302	. 1806
1. 99	. 1298	. 2326	. 5580	1. 720	.3598	1. 674	1, 62844	26. 104	30. 17	. 5791	4. 453	2. 652	1, 679	. 7255	. 1789
2. 00	.1278	. 2300	. 5556	1. 732	.3579	1. 688	1. 63299	26. 380	30, 00	. 5774	4, 500	2. 667	1. 688	. 7209	. 1773
2. 01	.1258	. 2275	. 5531	1. 744	.3559	1. 702	1. 63751	26. 655	29, 84	. 5757	4, 547	2. 681	1. 696	. 7162	. 1757
2. 02	.1239	. 2250	. 5506	1. 755	.3539	1. 716	1. 64201	26. 929	29, 67	. 5740	4, 594	2. 696	1. 704	. 7115	. 1741
2. 03	.1220	. 2225	. 5482	1. 767	.3518	1. 730	1. 64647	27. 203	29, 51	. 5723	4, 641	2. 711	1. 712	. 7069	. 1726
2. 04	.1201	. 2200	. 5458	1. 778	.3498	1. 745	1. 65090	27. 476	29, 35	. 5707	4, 689	2. 725	1. 720	. 7022	. 1710
2. 05	.1182	.2176	. 5433	1. 790	.3478	1. 760	1. 65530	27, 748	29. 20	. 5691	4. 736	2. 740	1. 729	. 6975	. 1695
2. 06	.1164	.2152	. 5409	1. 801	.3458	1. 775	1. 65967	28, 020	29. 04	. 5675	4. 784	2. 755	1. 737	. 6928	. 1680
2. 07	.1146	.2128	. 5385	1. 812	.3437	1. 790	1. 66402	28, 290	28. 89	. 5659	4. 832	2. 769	1. 745	. 6882	. 1665
2. 08	.1128	.2104	. 5361	1. 824	.3417	1. 806	1. 66833	28, 560	28. 74	. 5643	4. 881	2. 783	1. 754	. 6835	. 1651
2. 09	.1111	.2081	. 5337	1. 835	.3396	1. 821	1. 67262	28, 829	28. 59	. 5628	4. 929	2. 798	1. 762	. 6789	. 1636
2, 10	. 1094	. 2058	. 5313	1. 847	.3376	1, 837	1. 67687	29. 097	28. 44	. 5613	4. 978	2. 812	1. 770	. 6742	. 1622
2, 11	. 1077	. 2035	. 5290	1. 858	.3355	1, 853	1. 68110	29. 364	28. 29	. 5598	5. 027	2. 826	1. 779	. 6696	. 1608
2, 12	. 1060	. 2013	. 5266	1. 869	.3334	1, 869	1. 68530	29. 631	28. 14	. 5583	5. 077	2. 840	1. 787	. 6649	. 1594
2, 13	. 1043	. 1990	. 5243	1. 881	.3314	1, 885	1. 68947	29. 897	28. 00	. 5568	5. 126	2. 854	1. 796	. 6603	. 1580
2, 14	. 1027	. 1968	. 5219	1. 892	.3293	1, 902	1. 69362	30. 161	27. 86	. 5554	5. 176	2. 868	1. 805	. 6557	. 1567

#### EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

#### TABLE II,-SUPERSONIC FLOW-Continued

M or M <sub>1</sub>	$\frac{p}{p_t}$	<u>p</u>	$\frac{T}{T_i}$	β	$\frac{q}{p_t}$	$\frac{A}{A_{\bullet}}$	$\frac{V}{a_*}$	P	μ	M <sub>2</sub>	$\frac{p_2}{p_1}$	<u>P1</u> P1	$\frac{T_2}{T_1}$	$\frac{p_{i_2}}{p_{i_1}}$	$\frac{p_1}{p_{\ell_2}}$
2.15	.1011	. 1946	. 5196	1. 903	.3272	1, 919	1, 69774	30, 425	27, 72	.5540	5, 226	2.882	1, 813	. 6511	. 1553
2.16	.9956 -1	. 1925	. 5173	1. 915	.3252	1, 935	1, 70183	30, 689	27, 58	.5525	5, 277	2.896	1, 822	. 6464	. 1540
2.17	.9802 -1	. 1903	. 5150	1. 926	.3231	1, 953	1, 70589	30, 951	27, 44	.5511	5, 327	2.910	1, 831	. 6419	. 1527
2.18	.9649 -1	. 1882	. 5127	1. 937	.3210	1, 970	1, 70962	31, 212	27, 30	.5498	5, 378	2.924	1, 839	. 6373	. 1514
2.19	.9500 -1	. 1861	. 5104	1. 948	.3189	1, 987	1, 71393	31, 473	27, 17	.5484	5, 429	2.938	1, 848	. 6327	. 1502
2, 20	.9352 -1	.1841	.5081	1, 960	.3169	2, 005	1, 71791	31, 732	27, 04	.5471	5, 480	2, 951	1, 857	. 6281	.1489
2, 21	.9207 -1	.1820	.5059	1, 971	.3148	2, 023	1, 72187	31, 991	26, 90	.5457	5, 531	2, 965	1, 866	. 6236	.1476
2, 22	.9064 -1	.1800	.5036	1, 982	.3127	2, 041	1, 72579	32, 250	26, 77	.5444	5, 583	2, 978	1, 875	. 6191	.1464
2, 23	.8923 -1	.1780	.5014	1, 983	.3166	2, 059	1, 72970	32, 507	26, 64	.5431	5, 636	2, 992	1, 883	. 6145	.1452
2, 24	.8785 -1	.1790	.4991	2, 004	.3085	2, 078	1, 73357	32, 763	26, 51	.5418	5, 687	3, 005	1, 892	. 6100	.1440
2. 25	.8648 -1	.1740	. 4969	2, 016	.3065	2.096	1. 73742	33, 918	26, 39	.5406	5, 740	3, 019	1, 901	. 6055	.1428
2. 26	.8514 -1	.1721	. 4947	2, 027	.3044	2.115	1. 74125	33, 273	26, 26	.5393	5, 792	3, 032	1, 910	. 6011	.1417
2. 27	.8382 -1	.1702	. 4925	2, 038	.3023	2.134	1. 74504	33, 527	26, 14	.5381	5, 845	3, 045	1, 919	. 5966	.1405
2. 28	.8251 -1	.1683	. 4903	2, 049	.3003	2.154	1. 74882	33, 780	26, 01	.5368	5, 898	3, 058	1, 929	. 5921	.1394
2. 29	.8123 -1	.1664	. 4881	2, 060	.2982	2.173	1. 75257	34, 632	25, 89	.5356	5, 951	3, 071	1, 938	. 5877	.1382
2.30	.79971	. 1646	.4859	2.071	. 2961	2, 193	1, 75629	34, 283	25, 77	.5344	6, 905	3, 685	1, 947	.5833	.1371
2.31	.78731	. 1628	.4837	2.082	. 2941	2, 213	1, 75999	34, 583	25, 65	.5332	6, 059	3, 698	1, 956	.5789	.1360
2.32	.77511	. 1609	.4816	2.093	. 2920	2, 233	1, 76366	34, 783	25, 53	.5321	6, 113	3, 110	1, 965	.5745	.1349
2.33	.76311	. 1592	.4791	2.104	. 2900	2, 254	1, 76731	35, 081	25, 42	.5309	6, 167	3, 123	1, 974	.5702	.1338
2.34	.75121	. 1574	.4778	2.116	. 2879	2, 274	1, 77063	35, 279	25, 30	.5297	6, 222	3, 136	1, 984	.5658	.1328
2.35	.7396 -1	. 1556	. 4752	2, 127	. 2859	2, 295	1, 77453	35, 526	25. 18	.5286	6, 276	3, 149	1, 993	.5615	.1317
2.36	.7281 -1	. 1539	. 4731	2, 138	. 2839	2, 316	1, 77811	35, 771	25. 07	.5275	6, 331	3, 162	2, 002	.5572	.1307
2.37	.7168 -1	. 1522	. 4709	2, 149	. 2818	2, 338	1, 78166	36, 917	24. 96	.5264	6, 386	3, 174	2, 012	.5529	.1297
2.38	.7067 -1	. 1505	. 4688	2, 160	. 2798	2, 359	1, 78519	36, 261	24. 85	.5253	6, 442	3, 187	2, 021	.5486	.1286
2.39	.6948 -1	. 1488	. 4668	2, 171	. 2778	2, 381	1, 78869	36, 594	24. 73	.5242	6, 497	3, 199	2, 031	.5444	.1276
2, 40	.6840 -4	. 1472	. 4647	2, 182	. 2758	2, 403	1, 79218	36, 746	24. 62	.5231	6, 553	3, 212	2.040	.5401	.1266
2, 41	.6734 -4	. 1456	. 4626	2, 196	. 2738	2, 425	1, 79563	36, 988	24. 52	.5221	6, 609	3, 224	2.050	.5359	.1257
2, 42	.6630 -4	. 1439	. 4606	2, 204	. 2718	2, 448	1, 79607	37, 229	24. 41	.5210	6, 666	3, 237	2.059	.6317	.1247
2, 43	.6527 -1	. 1424	. 4585	2, 215	. 2698	2, 471	1, 80248	37, 469	24. 30	.5200	6, 722	3, 249	2.069	.5276	.1237
2, 44	.6426 -1	. 1468	. 4565	2, 226	. 2678	2, 494	1, 80587	37, 708	24. 19	.5189	6, 779	3, 261	2.079	.5234	.1228
2.45	.6327 -1	. 1392	. 4544	2, 237	. 2658	2, 517	1.80924	37, 946	24, 09	.5179	6, 836	3, 273	2, 088	.5193	.1218
2.46	.6229 -1	. 1377	. 4524	2, 248	. 2639	2, 540	1.81258	38, 183	23, 99	.5169	6, 894	3, 285	2, 098	.5152	.1209
2.47	.6183 -1	. 1362	. 4504	2, 259	. 2619	2, 564	1.81591	38, 420	23, 88	.5159	6, 951	3, 298	2, 108	.5111	.1200
2.48	.6038 -1	. 1346	. 4484	2, 269	. 2599	2, 588	1.81921	38, 655	23, 78	.5149	7, 069	3, 310	2, 118	.5071	.1191
2.49	.5945 -1	. 1332	. 4464	2, 280	. 2580	2, 612	1.82249	38, 890	23, 68	.5140	7, 067	3, 321	2, 128	.5030	.1182
2, 50	.5853 -1	. 1317	. 4444	2, 291	. 2561	2, 637	1. 82574	39. 124	23, 58	.5130	7, 125	3, 333	2, 138	.4990	.1173
2, 51	.5762 -1	. 1302	. 4425	2, 302	. 2541	2, 661	1. 82898	39. 357	23, 48	.5120	7, 183	3, 345	2, 147	.4930	.1164
2, 52	.5674 -1	. 1288	. 4405	2, 313	. 2522	2, 686	1. 83219	39. 589	23, 38	.5111	7, 242	3, 357	2, 157	.4911	.1155
2, 53	.5586 -1	. 1274	. 4386	2, 324	. 2503	2, 712	1. 83538	39. 820	23, 28	.5102	7, 301	3, 369	2, 167	.4871	.1147
2, 54	.5500 -1	. 1260	. 4366	2, 335	. 2484	2, 737	1. 83835	40. 059	23, 18	.5092	7, 360	3, 380	2, 177	.4832	.1138
2, 55	.5415 -4	. 1246	. 4347	2,346	. 2465	2, 763	1. 84170	40, 280	23, 09	.5083	7, 420	3, 392	2, 187	.4793	.1130
2, 56	.5332 -4	. 1232	. 4328	2,357	. 2446	2, 789	3. 84483	40, 509	22, 99	.5074	7, 479	3, 403	2, 198	.4754	.1122
2, 57	.5250 -5	. 1218	. 4309	2,367	. 2427	2, 815	1. 84794	40, 736	22, 91	.5065	7, 539	3, 415	2, 208	.4715	.113
2, 58	.5169 -1	. 1205	. 4289	2,378	. 2409	2, 842	1. 85103	40, 963	22, 81	.5056	7, 599	3, 426	2, 218	.4677	.1105
2, 59	.5090 -1	. 1192	. 4271	2,389	. 2390	2, 869	1. 85410	41, 189	22, 71	.5047	7, 659	3, 438	2, 228	.4639	.1097
2.60	.5012 -1	. 1179	.4252	2, 400	. 2371	2, 896	1. 85714	41, 415	22. 62	.5039	7, 720	3, 449	2, 288	.4601	.1089
2.61	.4935 -1	. 1166	.4233	2, 411	. 2353	2, 923	1. 86017	41, 639	22. 53	.5030	7, 781	3, 460	2, 249	.4564	.1081
2.62	.4850 -1	. 1153	.4214	2, 422	. 2335	2, 951	1. 86318	41, 863	22. 44	.5022	7, 842	3, 471	2, 259	.4526	.1074
2.63	.4784 -1	. 1140	.4196	2, 432	. 2317	2, 979	1. 86616	42, 056	22. 35	.5013	7, 903	3, 483	2, 269	.4489	.1098
2.64	.4711 -1	. 1128	.4177	2, 443	. 2298	3, 007	1. 86913	42, 307	22. 26	.5005	7, 965	3, 494	2, 280	.4452	.1058
2, 65	.4639 -1	.1115	.4159	2, 454	.2289	3, 036	1, 87208	42, 529	22.17	.4996	8, 026	3, 505	2, 290	.4416	. 1051
2, 66	.4568 -1	.1103	.4141	2, 465	.2262	3, 065	1, 87501	42, 749	22.08	.4988	8, 088	3, 516	2, 301	.4379	. 1043
2, 67	.4498 -1	.1091	.4122	2, 476	.2245	3, 094	1, 87702	42, 968	22.00	.4980	8, 150	3, 527	2, 311	.4343	. 1036
2, 68	.4429 -1	.1079	.4104	2, 486	.2227	3, 123	1, 88091	43, 187	21.91	.4972	8, 213	3, 537	2, 322	.4307	. 1028
2, 69	.4362 -1	.1067	.4086	2, 497	.2209	3, 153	1, 88368	43, 405	21.82	.4964	8, 275	3, 548	2, 332	.4271	. 1021
2.70	.4295 -1	. 1056	.4068	2, 508	.2192	3, 183	1, 88653	43, 621	21. 74	. 4956	8, 338	3, 559	2, 343	.4236	.1014
2.71	.4229 -1	. 1044	.4051	2, 519	.2174	3, 213	1, 88696	43, 838	21. 65	. 4949	8, 401	3, 570	2, 354	.4201	.1007
2.72	.4165 -1	. 1033	.4033	2, 530	.2157	3, 244	1, 89218	44, 053	21. 57	. 4941	8, 465	3, 580	2, 364	.4166	.9998 "t
2.73	.4102 -1	. 1022	.4015	2, 540	.2140	3, 275	1, 89497	44, 267	21. 49	. 4933	8, 528	3, 591	2, 375	.4131	.9929 -t
2.74	.4039 -1	. 1010	.3998	2, 551	.2123	4, 306	1, 89775	44, 481	21. 41	. 4926	8, 592	3, 601	2, 386	.4097	.9860 -1
2, 75	.3978 -1	.9694 -1	.3980	2, 562	.2106	3, 338	1. 90051	44.694	21, 32	.4918	8, 656	3, 612	2, 397	. 4062	.9792 -1
2, 76	.3917 -3	.9885 -1	.3963	2, 572	.2089	3, 370	1. 90325	44.906	21, 24	.4911	8, 721	3, 622	2, 407	. 4028	.9724 -1
2, 77	.3858 -1	.9778 -1	.3945	2, 583	.2072	3, 402	1. 90398	45.117	21, 16	.4903	8, 785	3, 633	2, 418	. 3994	.9658 -1
2, 78	.3799 -1	.9671 -1	.3928	2, 594	.2055	3, 434	1. 90808	45.327	21, 08	.4896	8, 830	3, 643	2, 429	. 3961	.9691 -1
2, 79	.3742 -1	.9566 -1	.3911	2, 605	.2039	3, 467	1. 91137	45.537	21, 00	.4889	8, 915	3, 653	2, 440	. 3928	.9626 -1
2.80	3685 -1	.9463 ~1	3894	2, 615	. 2022	3, 500	1, 91404	45.746	20, 92	. 4882	8, 980	3. 664	2. 451	.3895	.9461 -1
2.81	3629 -1	.9360 ~1	3877	2, 626	. 2006	3, 534	1, 91669	45.954	20, 85	. 4875	9, 045	3. 674	2. 462	.5862	.9397 -1
2.82	3574 -1	.9259 ~1	2860	2, 637	. 1990	3, 567	1, 91933	46.161	20, 77	. 4868	9, 111	3. 684	2. 473	.3829	.9334 -1
2.83	3520 -1	.9158 ~1	3844	2, 647	. 1973	3, 601	1, 92195	46.368	20, 69	. 4861	9, 177	3. 694	2. 484	.3797	.9271 -1
2.84	3467 -1	.9059 ~1	3827	2, 658	. 1957	3, 636	1, 92455	46.573	20, 62	. 4854	9, 243	3. 704	2. 496	.3765	.9208 -1
2.85	.3415 -1	.8962 -1	.3810	2, 669	. 1941	3. 671	1, 92714	46, 778	20, 54	. 4847	9. 310	3, 714	2, 507	.3733	. 9147 -1
2.86	.3363 -1	.8965 -1	.3794	2, 679	. 1926	3. 706	1, 92970	46, 982	20, 47	. 4840	9. 376	3, 724	2, 518	.3701	. 9086 -1
2.87	.3312 -1	.8769 -1	.3777	2, 690	. 1910	3. 741	1, 93225	47, 185	20, 39	. 4833	9. 443	3, 734	2, 529	.3670	. 9026 -3
2.88	.3263 -1	.8075 -1	.3761	2, 701	. 1894	3. 777	1, 93479	47, 388	20, 32	. 4827	9. 510	3, 743	2, 540	.3639	. 8966 -1
2.89	.3213 -1	.8581 -1	.3745	2, 711	. 1879	3. 813	1, 93731	47, 589	20, 24	. 4820	9. 577	3, 753	2, 552	.3608	. 8966 -5
2, 90	.3165 ~i	.8489 -1	.3729	2, 722	. 1863	3. 850	1. 93981	47, 790	20. 17	. 4814	9. 645	3. 763	2, 563	.3577	.8848 -1
2, 91	.3118 ~i	.8396 -1	.3712	2, 733	. 1848	3. 887	1. 94230	47, 990	20. 10	. 4807	9. 713	3. 773	2, 575	.3547	.8790 -1
2, 92	.3071 ~i	.8307 -1	.3696	2, 743	. 1833	3. 924	1. 94477	48, 190	20. 03	. 4801	9. 781	3. 782	2, 586	.3517	.8732 -1
2, 93	.3025 ~i	.8218 -1	.3681	2, 754	. 1818	3. 961	1. 94722	48, 388	19. 96	. 4795	9. 849	3. 792	2, 598	.3487	.8675 -1
2, 94	.2980 ~i	.8130 -1	.3665	2, 765	. 1803	3. 969	1. 94996	48, 586	19. 89	. 4788	9. 918	3. 801	2, 609	.3457	.8619 -1
2.95 2.96 2.97 2.98 2.99	.2905 -1 .2891 -1 .2848 -1 .2805 -1 .2764 -1	.8043 -1 .7957 -1 .7872 -1 .7788 -1 .7705 -1	.3649 .3633 .3618 .2602 .3587	2,775 2,786 2,797 2,807 2,818	.1788 .1773 .1758 .1744 .1729	4. 038 4. 076 4. 115 4. 155 4. 194	1, 95208 1, 95449 1, 95688 1, 95925 1, 96162	48, 783 48, 980 49, 175 49, 370 49, 564	19.81 19.75 19.68 19.61 19.54	.4782 .4776 .4770 .4764 .4758	9. 986 10. 06 10. 12 10. 19 10. 26	3, 811 3, 820 3, 829 3, 839 3, 848	2. 621 2. 632 2. 644 2. 656 2. 667	.3428 .3398 .3369 .3340 .3312	.8507 -1 .8453 -1 .8398 -1 .8345 -1
3. 00	. 2722 -1	.7623 -:	.3571	2. 828	.1715	4. 235	1, 96396	49. 757	19. 47	. 4752	10.33	3.857	2, 679	.3283	. 8291 -1
3. 01	. 2682 -1	.7541 -:	.3556	2. 839	.1701	4. 275	1, 96629	49. 950	19. 40	. 4746	10.40	3.866	2, 691	.3255	. 8238 -1
3. 02	. 2642 -1	.7461 -:	.3541	2. 850	.1687	4. 316	1, 96861	50. 142	19. 34	. 4740	10.47	3.875	2, 703	.3227	. 8186 -1
3. 03	. 2603 -1	.7382 -:	.3526	2. 860	.1673	4. 357	1, 97091	50. 333	19. 27	. 4734	10.54	3.884	2, 714	.3200	. 8134 -1
3. 04	. 2564 -1	.7303 -:	.3511	2. 871	.1659	4. 399	1, 97319	50. 523	19. 20	. 4729	10.62	3.893	2, 726	.3172	. 8063 -1

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## TABLE II.—SUPERSONIC FLOW—Continued

	1						$\gamma = 7/5$	5							
$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho_t}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{t_2}}$
3. 05	. 2526 1	$\begin{array}{cccc} .7226 & -1 \\ .7149 & -1 \\ .7074 & -1 \\ .6999 & -1 \\ .6925 & -1 \\ \end{array}$	. 3496	2. 881	. 1645	4. 441	1. 97547	50. 713	19. 14	. 4723	10. 69	3. 902	2. 738	. 3145	. 8032 -1
3. 06	. 2489 -1		. 3481	2. 892	. 1631	4. 483	1. 97772	50. 902	19. 07	. 4717	10. 76	3. 911	2. 750	. 3118	. 7982 -1
3. 07	. 2452 -1		. 3466	2. 903	. 1618	4. 526	1. 97997	51. 090	19. 01	. 4712	10. 83	3. 920	2. 762	. 3091	. 7932 -1
3. 08	. 2416 -1		. 3452	2. 913	. 1604	4. 570	1. 98219	51. 277	18. 95	. 4706	10. 90	3. 929	2. 774	. 3065	. 7882 -1
3. 09	. 2380 -1		. 3437	2. 924	. 1591	4. 613	1. 98441	51. 464	18. 88	. 4701	10. 97	3. 938	2. 786	. 3038	. 7833 -1
3. 10	. 2345 -1	. 6852 -1	. 3422	2. 934	. 1577	4. 657	1. 98661	51. 650	18. 82	. 4695	11. 05	3. 947	2. 799	. 3012	.7785 -1
3. 11	. 2310 -1	. 6779 -1	. 3408	2. 945	. 1564	4. 702	1. 98879	51. 835	18. 76	. 4690	11. 12	3. 955	2. 811	. 2986	.7737 -1
3. 12	. 2276 -1	. 6708 -1	. 3393	2. 955	. 1551	4. 747	1. 99097	52. 020	18. 69	. 4685	11. 19	3. 964	2. 823	. 2960	.7689 -1
3. 13	. 2243 -1	. 6637 -1	. 3379	2. 966	. 1538	4. 792	1. 99313	52. 203	18. 63	. 4679	11. 26	3. 973	2. 835	. 2935	.7642 -1
3. 14	. 2210 -1	. 6568 -1	. 3365	2. 977	. 1525	4. 838	1. 99527	52. 386	18. 57	. 4674	11. 34	3. 981	2. 848	. 2910	.7595 -1
3. 15	. 2177 -1	. 6499 -1	. 3351	2. 987	. 1512	4. 884	1. 99740	52. 569	18. 51	. 4669	11. 41	3. 990	2. 860	. 2885	.7549 -1
3. 16	. 2146 -1	. 6430 -1	. 3337	2. 998	. 1500	4. 930	1. 99952	52. 751	18. 45	. 4664	11. 48	3. 998	2. 872	. 2860	.7503 -1
3. 17	. 2114 -1	. 6363 -1	. 3323	3. 008	. 1487	4. 977	2. 00162	52. 931	18. 39	. 4659	11. 56	4. 006	2. 885	. 2835	.7457 -1
3. 18	. 2083 -1	. 6296 -1	. 3309	3. 019	. 1475	5. 025	2. 00372	53. 112	18. 33	. 4654	11. 63	4. 015	2. 897	. 2811	.7412 -1
3. 19	. 2053 -1	. 6231 -1	. 3295	3. 029	. 1462	5. 073	2. 00579	53. 292	18. 27	. 4648	11. 71	4. 023	2. 909	. 2786	.7367 -1
3. 20	. 2023 -1	. 6165 — 1	. 3281	3. 040	.1450	5. 121	2. 00786	53. 470	18. 21	. 4643	11. 78	4. 031	2. 922	. 2762	. 7323 -1
3. 21	. 1993 -1	. 6101 — 1	. 3267	3. 050	.1438	5. 170	2 00991	53. 648	18. 15	. 4639	11. 85	4. 040	2. 935	. 2738	. 7279 -1
3. 22	. 1964 -1	. 6037 — 1	. 3253	3. 061	.1426	5. 219	2. 01195	53. 826	18. 09	. 4634	11. 93	4. 048	2. 947	. 2715	. 7235 -1
3. 23	. 1936 -1	. 5975 — 1	. 3240	3. 071	.1414	5. 268	2. 01398	54. 003	18. 03	. 4629	12. 01	4. 056	2. 960	. 2691	. 7192 -1
3. 24	. 1908 -1	. 5912 — 1	. 3226	3. 082	.1402	5. 319	2. 01599	54. 179	17. 98	. 4624	12. 08	4. 064	2. 972	. 2668	. 7149 -1
3, 25	. 1880 -1	. 5851 -1	. 3213	3. 092	. 1390	5. 369	2. 01799	54. 355	17. 92	. 4619	12. 16	4. 072	2. 985	. 2645	.7107 -1
3, 26	. 1853 -1	. 5790 -1	. 3199	3. 103	. 1378	5. 420	2. 01998	54. 529	17. 86	. 4614	12. 23	4. 080	2. 998	. 2622	.7065 -1
3, 27	. 1826 -1	. 5730 -1	. 3186	3. 113	. 1367	5. 472	2. 02196	54. 703	17. 81	. 4610	12. 31	4. 088	3. 011	. 2600	.7023 -1
3, 28	. 1799 -1	. 5671 -1	. 5173	3. 124	. 1355	5. 523	2. 02392	54. 877	17. 75	. 4605	12. 38	4. 096	3. 023	. 2577	.6982 -1
3, 29	. 1773 -1	. 5612 -1	. 3160	3. 134	. 1344	5. 576	2. 02587	55. 050	17. 70	. 4600	12. 46	4. 104	3. 036	. 2555	.6941 -1
3.30	. 1748 -1	. 5554 -1	.3147	3. 145	. 1332	5, 629	2. 02781	55, 222	17. 64	. 4596	12. 54	4. 112	3. 049	. 2533	.6900 -1
3.31	. 1722 -1	. 5497 -1	.3134	3. 155	. 1321	5, 682	2. 02974	55, 393	17. 58	. 4591	12. 62	4. 120	3. 062	. 2511	.6860 -1
3.32	. 1698 -1	. 5440 -1	.3121	3. 166	. 1310	5, 736	2. 03165	55, 564	17. 53	. 4587	12. 69	4. 128	3. 075	. 2489	.6820 -1
3.33	. 1673 -1	. 5384 -1	.3108	3. 176	. 1299	5, 790	2. 03356	55, 734	17. 48	. 4582	12. 77	4. 135	3. 088	. 2468	.6781 -1
3.34	. 1649 -1	. 5329 -1	.3095	3. 187	. 1288	5, 845	2. 03545	55, 904	17. 42	. 4578	12. 85	4. 143	3. 101	. 2446	.6741 -1
3.35	. 1625 -1	. 5274 -1	. 3082	3. 197	. 1277	5. 900	2. 03733	56. 073	17. 37	. 4573	12, 93	4. 151	3. 114	. 2425	.6702 -1
3.36	. 1602 -1	. 5220 -1	. 3069	3. 208	. 1266	5. 956	2. 03920	56. 241	17. 31	. 4569	13, 00	4. 158	3. 127	. 2404	.6664 -1
3.37	. 1579 -1	. 5166 -1	. 3057	3. 218	. 1255	6. 012	2. 04106	56. 409	17. 26	. 4565	13, 08	4. 166	3. 141	. 2383	.6626 -1
3.38	. 1557 -1	. 5113 -1	. 3044	3. 229	. 1245	6. 069	2. 04290	56. 576	17. 21	. 4560	13, 16	4. 173	3. 154	. 2363	.6588 -1
3.39	. 1534 -1	. 5061 -1	. 3032	3. 239	. 1234	6. 126	2. 04474	56. 742	17. 16	. 4556	13, 24	4. 181	3. 167	. 2342	.6550 -1
3. 40	. 1512 -1	. 5009 -1	. 3019	3, 250	.1224	6. 184	2. 04656	56, 907	17. 10	. 4552	13. 32	4. 188	3. 180	. 2322	. 6513 -1
3. 41	. 1491 -1	4958 -1	. 3007	3, 260	.1214	6. 242	2. 04837	57, 073	17. 05	. 4548	13. 40	4. 196	3. 194	. 2302	. 6476 -1
3. 42	. 1470 -1	. 4908 -1	. 2995	3, 271	.1203	6. 301	2. 05017	57, 237	17. 00	. 4544	13. 48	4. 203	3. 207	. 2282	. 6439 -1
3. 43	. 1449 -1	. 4858 -1	. 2982	3, 281	.1193	6. 360	2. 05196	57, 401	16. 95	. 4540	13. 56	4. 211	3. 220	. 2263	. 6403 -1
3. 44	. 1428 -1	. 4808 -1	. 2970	3, 291	.1183	6. 420	2. 05374	57, 564	16. 90	. 4535	13. 64	4. 218	3. 234	. 2243	. 6367 -1
3. 45	.1408 -1	. 4759 -1	. 2958	3.302	. 1173	6. 480	2. 05551	57. 726	16. 85	. 4531	13. 72	4. 225	3. 247	. 2224	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
3. 46	.1388 -1	. 4711 -1	. 2946	3.312	. 1163	6. 541	2. 05727	57. 888	16. 80	. 4527	13. 80	4. 232	3. 261	. 2205	
3. 47	.1368 -1	. 4663 -1	. 2934	3.323	. 1153	6. 602	2. 059,01	58. 050	16. 75	. 4523	13. 88	4. 240	3. 274	. 2186	
3. 48	.1349 -1	. 4616 -1	. 2922	3.333	. 1144	6. 664	2. 06075	58. 210	16. 70	. 4519	13. 96	4. 247	3. 288	. 2167	
3. 49	.1330 -1	. 4569 -1	. 2910	3.344	. 1134	6. 727	2. 06247	58. 370	16. 65	. 4515	14. 04	4. 254	3. 301	. 2148	
3.50	. 1311 -1	. 4523 -1	. 2899	3.354	. 1124	6. 790	2. 06419	58, 530	16. 60	. 4512	14. 13	4. 261	3. 315	. 2129	. 6157 -1
3.51	. 1293 -1	. 4478 -1	. 2887	3.365	. 1115	6. 853	2. 06589	58, 689	16. 55	. 4508	14. 21	4. 268	3. 329	. 2111	. 6123 -1
3.52	. 1274 -1	. 4433 -1	. 2875	3.375	. 1105	6. 917	2. 06759	58, 847	16. 51	. 4504	14. 29	4. 275	3. 343	. 2093	. 6089 -1
3.53	. 1256 -1	. 4388 -1	. 2864	3.385	. 1096	6. 982	2. 06927	59, 004	16. 46	. 4500	14. 37	4. 282	3. 356	. 2075	. 6056 -1
3.54	. 1239 -1	. 4344 -1	. 2852	3.396	. 1087	7. 047	2. 07094	59, 162	16. 41	. 4496	14. 45	4. 289	3. 370	. 2057	. 6023 -1
3, 55	. 1221 -1	. 4300 -1	. 2841	3. 406	. 1078	7. 113	2. 07261	59. 318	16. 36	. 4492	14. 54	4. 296	3. 384	. 2039	. 5990 -1
3, 56	. 1204 -1	. 4257 -1	. 2829	3. 417	. 1069	7. 179	2. 07426	59. 474	16. 31	. 4489	14. 62	4. 303	3. 398	. 2022	. 5957 -1
3, 57	. 1188 -1	. 4214 -1	. 2818	3. 427	. 1059	7. 246	2. 07590	59. 629	16. 27	. 4485	14. 70	4. 309	3. 412	. 2004	. 5925 -1
3, 58	. 1171 -1	. 4172 -1	. 2806	3. 437	. 1051	7. 313	2. 07754	59. 784	16. 22	. 4481	14. 79	4. 316	3. 426	. 1987	. 5892 -1
3, 59	. 1155 -1	. 4131 -1	. 2795	3. 448	. 1042	7. 382	2. 07916	59. 938	16. 17	. 4478	14. 87	4. 323	3. 440	. 1970	. 5861 -1
3. 60	.1138 -1	. 4089 -1	. 2784	3. 458	. 1033	7. 450	2. 08077	60. 091	16. 13	. 4474	14. 95	4. 330	3. 454	. 1953	. 5829 -1
3. 61	.1123 -1	. 4049 -1	. 2773	3. 469	. 1024	7. 519	2. 08238	60. 244	16. 08	. 4471	15. 04	4. 336	3. 468	. 1936	. 5798 -1
3. 62	.1107 -1	. 4008 -1	. 2762	3. 479	. 1016	7. 589	2. 08397	60. 397	16. 04	. 4467	15. 12	4. 343	3. 482	. 1920	. 5767 -1
3. 63	.1092 -1	. 3968 -1	. 2751	3. 490	. 1007	7. 659	2. 08556	60. 549	15. 99	. 4463	15. 21	4. 350	3. 496	. 1903	. 5736 -1
3. 64	.1076 -1	. 3929 -1	. 2740	3. 500	. 9984 -1	7. 730	2. 08713	60. 700	15. 95	. 4460	15. 29	4. 356	3. 510	. 1887	. 5705 -1
3. 65	. 1062 -1	3890 -1	. 2729	3. 510	. 9900 -1	7. 802	2. 08870	60. 851	15. 90	. 4456	15. 38	4. 363	3. 525	. 1871	. 5675 -1
3. 66	. 1047 -1	3852 -1	. 2718	3. 521	. 9817 -1	7. 874	2. 09026	61. 000	15. 86	. 4453	15. 46	4. 369	3. 539	. 1855	. 5645 -1
3. 67	. 1032 -1	3813 -1	. 2707	3. 531	. 9734 -1	7. 947	2. 09180	61. 150	15. 81	. 4450	15. 55	4. 376	3. 553	. 1839	. 5615 -1
3. 68	. 1018 -1	3776 -1	. 2697	3. 542	. 9652 -1	8. 020	2. 09334	61. 299	15. 77	. 4446	15. 63	4. 382	3. 568	. 1823	. 5585 -1
3. 69	. 1004 -1	3739 -1	. 2686	3. 552	. 9570 -1	8. 094	2. 09487	61. 447	15. 72	. 4443	15. 72	4. 388	3. 582	. 1807	. 5556 -1
3 70	. 9903 -2	3702 -1	. 2675	3. 562	. 9490 -1	8, 169	2. 09639	61. 595	15. 68	. 4439	15. 81	4. 395	3. 596	. 1792	. 5526 -1
3,71	. 9767 -2	3665 -1	. 2665	3. 573	. 9410 -1	8, 244	2. 09790	61. 743	15. 64	. 4436	15. 89	4. 401	3. 611	. 1777	. 5497 -1
3,72	. 9633 -2	3629 -1	. 2654	3. 583	. 9331 -1	8, 320	2. 09941	61. 889	15. 59	. 4433	15. 98	4. 408	3. 625	. 1761	. 5469 -1
3,73	. 9500 -2	3594 -1	. 2644	3. 593	. 9253 -1	8, 397	2. 10090	62. 036	15. 55	. 4430	16. 07	4. 414	3. 640	. 1746	. 5440 -1
3,74	. 9370 -2	3558 -1	. 2633	3. 604	. 9175 -1	8, 474	2. 10238	62. 181	15. 51	. 4426	16. 15	4. 420	3. 654	. 1731	. 5412 -1
3. 75	. 9242 -2	. 3524 -1	. 2623	3. 614	. 9098 -1	8, 552	2. 10386	62. 326	15. 47	. 4423	16. 24	4. 426	3. 669	. 1717	. 5384 -1
3. 76	. 9116 -2	. 3489 -1	. 2613	3. 625	. 9021 -1	8, 630	2. 10533	62. 471	15. 42	. 4420	16. 33	4. 432	3. 684	. 1702	. 5356 -1
3. 77	. 8991 -2	. 3455 -1	. 2602	3. 635	. 8945 -1	8, 709	2. 10679	62. 615	15. 38	. 4417	16. 42	4. 439	3. 698	. 1687	. 5328 -1
3. 78	. 8869 -2	. 3421 -1	. 2592	3. 645	. 8870 -1	8, 789	2. 10824	62. 758	15. 34	. 4414	16. 50	4. 445	3. 713	. 1673	. 5301 -1
3. 79	. 8748 -2	. 3388 -1	. 2582	3. 656	. 8796 -1	8, 870	2. 10968	62. 901	15. 30	. 4410	16. 59	4. 451	3. 728	. 1659	. 5274 -1
3. 80	. 8629 -2	. 3355 -1	. 2572	3. 666	. 8722 -1	8, 951	2. 11111	63. 044	15. 26	. 4407	16. 68	4. 457	3. 743	. 1645	. 5247 -1
3. 81	. 8512 -2	. 3322 -1	. 2562	3. 676	. 8649 -1	9, 032	2. 11254	63. 186	15. 22	. 4404	16. 77	4. 463	3. 758	. 1631	. 5220 -1
3. 82	. 8396 -2	. 3290 -1	. 2552	3. 687	. 8577 -1	9, 115	2. 11395	63. 327	15. 18	. 4401	16. 86	4. 469	3. 772	. 1617	. 5193 -1
3. 83	. 8283 -2	. 3258 -1	. 2542	3. 697	. 8505 -1	9, 198	2. 11536	63. 468	15. 14	. 4398	16. 95	4. 475	3. 787	. 1603	. 5167 -1
3. 84	. 8171 -2	. 3227 -1	. 2532	3. 708	. 8434 -1	9, 282	2. 11676	63. 608	15. 10	. 4395	17. 04	4. 481	3. 802	. 1589	. 5140 -1
3. 85	. 8060 ··2	.3195 -1	. 2522	3. 718	. 8363 -1	9. 366	2. 11815	63. 748	15. 06	. 4392	17. 13	4. 487	3. 817	. 1576	. 5114 -1
3. 86	. 7951 ·-2	.3165 -1	. 2513	3. 728	. 8293 -1	9. 451	2. 11954	63. 887	15. 02	. 4389	17. 22	4. 492	3. 832	. 1563	. 5089 -1
3. 87	. 7844 ·-2	.3134 -1	. 2503	3. 739	. 8224 -1	9. 537	2. 12091	64. 026	14. 98	. 4386	17. 31	4. 498	3. 847	. 1549	. 5063 -1
3. 88	. 7739 ·-2	.3104 -1	. 2493	3. 749	. 8155 -1	9. 624	2. 12228	64. 164	14. 94	. 4383	17. 40	4. 504	3. 863	. 1536	. 5038 -1
3. 89	. 7635 ·-2	.3074 -1	. 2484	3. 759	. 8087 -1	9. 711	2. 12364	64. 302	14. 90	. 4380	17. 49	4. 510	3. 878	. 1523	. 5012 -1
3. 90	. 7532 -2	.3044 -1	. 2474	3. 770	. 8019 -1	9. 799	2. 12499	64. 440	14. 86	. 4377	17. 58	4. 516	3, 893	. 1510	. 4987 -1
3. 91	. 7431 -2	.3015 -1	. 2464	3. 780	. 7952 -1	9. 888	2. 12634	64. 576	14. 82	. 4375	17. 67	4. 521	3, 908	. 1497	. 4962 -1
3. 92	. 7332 -2	.2986 -1	. 2455	3. 790	. 7886 -1	9. 977	2. 12767	64. 713	14. 78	. 4372	17. 76	4. 527	3, 923	. 1485	. 4938 -1
3. 93	. 7233 -2	.2958 -1	. 2446	3. 801	. 7820 -1	10. 07	2. 12900	64. 848	14. 74	. 4369	17. 85	4. 533	3, 939	. 1472	. 4913 -1
3. 94	. 7137 -2	.2929 -1	. 2436	3. 811	. 7755 -1	10. 16	2. 13032	64. 983	14. 70	. 4366	17. 94	4. 538	3, 954	. 1460	. 4889 -1

#### EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

#### TABLE II.—SUPERSONIC FLOW—Continued

$M \\  ext{or} \\ M_1$	$\frac{p}{p_t}$	ρ ρι	$rac{T}{T_t}$	β	$\frac{q}{p_t}$	$rac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	<u>ρ2</u> ρ1	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
3. 95	. 7042 -2	. 2902 -1	. 2427	3. 821	. 7691 -1	10. 25	2. 13163	65, 118	14. 67	. 4363	18. 04	4. 544	3. 969	. 1448	. 4865 -1
3. 96	. 6948 -2	. 2874 -1	. 2418	3. 832	. 7627 -1	10. 34	2. 13294	65, 253	14. 63	. 4360	18. 13	4. 549	3. 985	. 1435	. 4841 -1
3. 97	. 6855 -2	. 2846 -1	. 2408	3. 842	. 7563 -1	10. 44	2. 13424	65, 386	14. 59	. 4358	18. 22	4. 555	4. 000	. 1423	. 4817 -1
3. 98	. 6764 -2	. 2819 -1	. 2399	3. 852	. 7500 -1	10. 53	2. 13553	65, 520	14. 55	. 4355	18. 31	4. 560	4. 016	. 1411	. 4793 -1
3. 99	. 6675 -2	. 2793 -1	. 2390	3. 863	. 7438 -1	10. 62	2. 13681	65, 652	14. 55	. 4352	18. 41	4. 566	4. 031	. 1399	. 4770 -1
4. 00	.6586 -2	$\begin{array}{cccc} .\ 2766 & -1 \\ .\ 2740 & -1 \\ .\ 2714 & -1 \\ .\ 2688 & -1 \\ .\ 2663 & -1 \\ \end{array}$	. 2381	3. 873	. 7376 -1	10. 72	2. 13809	65. 785	14. 48	. 4350	18. 50	4, 571	4. 047	. 1388	. 4747 -1
4. 01	.6499 -2		. 2372	3. 883	. 7315 -1	10. 81	2. 13936	65. 917	14. 44	. 4347	18. 59	4, 577	4. 062	. 1376	. 4723 -1
4. 02	.6413 -2		. 2363	3. 894	. 7255 -1	10. 91	2. 14062	66. 048	14. 40	. 4344	18. 69	4, 582	4. 078	. 1364	. 4700 -1
4. 03	.6528 -2		. 2354	3. 904	. 7194 -1	11. 01	2. 14188	66. 179	14. 37	. 4342	18. 78	4, 588	4. 094	. 1353	. 4678 -1
4. 04	.6245 -2		. 2345	3. 914	. 7135 -1	11. 11	2. 14312	66. 309	14. 33	. 4339	18. 88	4, 593	4. 110	. 1342	. 4655 -1
4. 05	.6163 2	. 2638 -1	. 2336	3. 925	. 7076 -1	11. 21	2. 14436	66, 439	14. 30	. 4336	18. 97	4. 598	4. 125	. 1330	. 4633 -1
4. 06	.6082 -2	. 2613 -1	. 2327	3. 935	. 7017 -1	11. 31	2. 14560	66, 569	14. 26	. 4334	19. 06	4. 604	4. 141	. 1319	. 4610 -1
4. 07	.6002 -2	. 2589 -1	. 2319	3. 945	. 6959 -1	11. 41	2. 14682	66, 698	14. 22	. 4331	19. 16	4. 609	4. 157	. 1308	. 4588 -1
4. 08	.5923 -2	. 2564 -1	. 2310	3. 956	. 6902 -1	11. 51	2. 14804	66, 826	14. 19	. 4329	19. 25	4. 614	4. 173	. 1297	. 4566 -1
4. 09	.5845 -2	. 2540 -1	. 2301	3. 966	. 6845 -1	11. 61	2. 14926	66, 954	14. 15	. 4326	19. 35	4. 619	4. 189	. 1286	. 4544 -1
4. 10	.5769 -2	. 2516 -1	. 2293	3. 976	. 6788 -1	11. 71	2. 15046	67. 082	14. 12	. 4324	19. 45	4. 624	4. 205	. 1276	. 4523 -1
4. 11	.5694 -2	. 2493 -1	. 2284	3. 986	. 6732 -1	11. 82	2. 15166	67. 209	14. 08	. 4321	19. 54	4. 630	4. 221	. 1265	. 4501 -1
4. 12	.5619 -2	. 2470 -1	. 2275	3. 997	. 6677 -1	11. 92	2. 15285	67. 336	14. 05	. 4319	19. 64	4. 635	4. 237	. 1254	. 4480 -1
4. 13	.5546 -2	. 2447 -1	. 2267	4. 007	. 6622 -1	12. 03	2. 15404	67. 462	14. 01	. 4316	19. 73	4. 640	4. 253	. 1244	. 4459 -1
4. 14	.5474 -2	. 2424 -1	. 2258	4. 017	. 6568 -1	12. 14	2. 15522	67. 588	13. 98	. 4314	19. 83	4. 645	4. 269	. 1234	. 4438 -1
4. 15	.5403 -2	. 2401 -1	. 2250	4. 028	. 6514 -1	12. 24	2. 15639	67, 713	13. 94	. 4311	19. 93	4. 650	4. 285	. 1223	. 4417 -!
4. 16	.5333 -2	. 2379 -1	. 2242	4. 038	. 6460 -1	12. 35	2. 15756	67, 828	13. 91	. 4809	20. 02	4. 655	4. 301	. 1213	. 4396 -1
4. 17	.5264 -2	. 2357 -1	. 2233	4. 048	. 6407 -1	12. 46	2. 15871	67, 963	13. 88	. 4306	20. 12	4. 660	4. 318	. 1203	. 4375 -1
4. 18	.5195 -2	. 2335 -1	. 2225	4. 059	. 6354 -1	12. 57	2. 15987	68, 087	13. 84	. 4304	20. 22	4. 665	4. 334	. 1193	. 4355 -1
4. 19	.5128 -2	. 2313 -1	. 2217	4. 069	. 6302 -1	12. 68	2. 16101	68, 210	13. 81	. 4302	20. 32	4. 670	4. 350	. 1183	. 4334 -1
4. 20	.5062 -2	. 2292 -1	. 2208	4. 079	. 6251 -1	12. 79	2. 16215	68. 333	13. 77	. 4299	20. 41	4. 675	4. 367	. 1173	. 4314 -1
4. 21	.4997 -2	. 2271 -1	. 2200	4. 090	. 6200 -1	12. 90	2. 16329	68. 456	13. 74	. 4297	20. 51	4. 680	4. 383	. 1164	. 4294 -1
4. 22	.4932 -2	. 2250 -1	. 2192	4. 100	. 6149 -1	13. 02	2. 16442	68. 578	13. 71	. 4295	20. 61	4. 685	4. 399	. 1154	. 4274 -1
4. 23	.4869 -2	. 2229 -1	. 2184	4. 110	. 6098 -1	13. 13	2. 16554	68. 700	13. 67	. 4292	20. 71	4. 690	4. 416	. 1144	. 4255 -1
4. 24	.4806 -2	. 2209 -1	. 2176	4. 120	. 6049 -1	13. 25	2. 16665	68. 821	13. 64	. 4290	20. 81	4. 694	4. 432	. 1135	. 4235 -1
4. 25	. 4745 -2	. 2189 -1	. 2168	4. 131	. 5999 -1	13. 36	2. 16776	68. 942	13. 61	. 4288	20. 91	4. 699	4. 449	. 1126	. 4215 -1
4. 26	. 4684 -2	. 2169 -1	. 2160	4. 141	. 5950 -1	13. 48	2. 16886	69. 063	13. 58	. 4286	21. 01	4. 704	4. 466	. 1116	. 4196 -1
4. 27	. 4624 -2	. 2149 -1	. 2152	4. 151	. 5902 -1	13. 60	2. 16996	69. 183	13. 54	. 4283	21. 11	4. 709	4. 482	. 1107	. 4177 -1
4. 28	. 4565 -2	. 2129 -1	. 2144	4. 162	. 5854 -1	13. 72	2. 17105	69. 302	13. 51	. 4281	21. 20	4. 713	4. 499	. 1098	. 4158 -1
4. 29	. 4507 -2	. 2110 -1	. 2136	4. 172	. 5806 -1	13. 83	2. 17214	69. 422	13. 48	. 4279	21. 30	4. 718	4. 516	. 1089	. 4139 -1
4. 30	$\begin{array}{cccc} .4449 & ^{-2} \\ .4393 & ^{-2} \\ .4337 & ^{-2} \\ .4282 & ^{-2} \\ .4228 & ^{-2} \end{array}$	. 2090 -1	. 2129	4. 182	. 5759 -1	13. 95	2. 17321	69. 541	13. 45	. 4277	21. 41	4. 723	4. 532	. 1080	. 4120 -1
4. 31		. 2071 -1	. 2121	4. 192	. 5712 -1	14. 08	2. 17429	69. 659	13. 42	. 4275	21. 51	4. 728	4. 549	. 1071	. 4101 -1
4. 32		. 2052 -1	. 2113	4. 203	. 5666 -1	14. 20	2. 17535	69. 777	13. 38	. 4272	21. 61	4. 732	4. 566	. 1062	. 4082 -1
4. 33		. 2034 -1	. 2105	4. 213	. 5620 -1	14. 32	2. 17642	69. 895	13. 35	. 4270	21. 71	4. 737	4. 583	. 1054	. 4064 -1
4. 34		. 2015 -1	. 2098	4. 223	. 5574 -1	14. 45	2. 17747	70. 012	13. 32	. 4268	21. 81	4. 741	4. 600	. 1045	. 4046 -1
4. 35	. 4174 -2	. 1997 -1	. 2090	4. 233	. 5529 -1	14. 57	2. 17852	70. 128	13. 29	. 4266	21. 91	4. 746	4. 617	. 1036	. 4027 -1
4. 36	. 4121 -2	. 1979 -1	. 2083	4. 244	. 5484 -1	14. 70	2. 17956	70. 245	13. 26	. 4264	22. 01	4. 751	4. 633	. 1028	. 4009 -1
4. 37	. 4069 -2	. 1961 -1	. 2075	4. 254	. 5440 -1	14. 82	2. 18060	70. 361	13. 23	. 4262	22. 11	4. 755	4. 651	. 1020	. 3991 -1
4. 38	. 4018 -2	. 1944 -1	. 2067	4. 264	. 5396 -1	14. 95	2. 18163	70. 476	13. 20	. 4260	22. 22	4. 760	4. 668	. 1011	. 3973 -1
4. 39	. 3968 -2	. 1926 -1	. 2060	4. 275	. 5352 -1	15. 08	2. 18266	70. 591	13. 17	. 4258	22. 32	4. 764	4. 685	. 1003	. 3956 -1
4. 40	3918 -2	. 1909 -1	. 2053	4. 285	. 5309 -1	15. 21	2. 18368	70. 706	13. 14	. 4255	22. 42	4. 768	4. 702	. 9948 -1	. 3938 -1
4. 41	.3868 -2	. 1892 -1	. 2045	4. 295	. 5266 -1	15. 34	2. 18470	70. 820	13. 11	. 4253	22. 52	4. 773	4. 719	. 9867 -1	. 3921 -1
4. 42	.3820 -2	. 1875 -1	. 2038	4. 305	. 5224 -1	15. 47	2. 18571	70. 934	13. 08	. 4251	22. 63	4. 777	4. 736	. 9787 -1	. 3903 -1
4. 43	.3772 -2	. 1858 -1	. 2030	4. 316	. 5182 -1	15. 61	2. 18671	71. 048	13. 05	. 4249	22. 73	4. 782	4. 783	. 9707 -1	. 3886 -1
4. 44	.3725 -2	. 1841 -1	. 2023	4. 326	. 5140 -1	15. 74	2. 187714	71. 161	13. 02	. 4247	22. 83	4. 786	4. 771	. 9628 -1	. 3869 -1
4. 45	.3678 -2	$\begin{array}{cccc} .1825 & -1 \\ .1808 & -1 \\ .1792 & -1 \\ .1776 & -1 \\ .1761 & -1 \\ \end{array}$	. 2016	4. 336	. 5099 -1	15. 87	2. 188708	71. 274	12. 99	. 4245	22. 94	4. 790	4. 788	. 9550 -1	. 3852° -1
4. 46	.3633 -2		. 2009	4. 346	. 5058 -1	16. 01	2. 189697	71. 386	12. 96	. 4243	23. 04	4. 795	4. 805	. 9473 -1	. 3835 -1
4. 47	.3587 -2		. 2002	4. 357	. 5017 -1	16. 15	2. 190681	71. 498	12. 93	. 4241	23. 14	4. 799	4. 823	. 9396 -1	. 3818 -1
4. 48	.3543 -2		. 1994	4. 367	. 4977 -1	16. 28	2. 191659	71. 610	12. 90	. 4239	23. 25	4. 803	4. 840	. 9320 -1	. 3801 -1
4. 49	.3499 -2		. 1987	4. 377	. 4937 -1	16. 42	2. 192632	71. 721	12. 87	. 4237	23. 35	4. 808	4. 858	. 9244 -1	. 3785 -1
4. 50	3455 -2	$\begin{array}{cccc} .1745 & -1 \\ .1729 & -1 \\ .1714 & -1 \\ .1699 & -1 \\ .1684 & -1 \\ \end{array}$	. 1980	4. 387	. 4898 -1	16. 56	2. 193600	71. 832	12. 84	. 4236	23. 46	4.812	4. 875	. 9170 -1	. 3768 -1
4. 51	3412 -2		. 1973	4. 398	. 4859 -1	16. 70	2. 194563	71. 942	12. 81	. 4234	23. 56	4.816	4. 893	. 9096 -1	. 3752 -1
4. 52	3370 -2		. 1966	4. 408	. 4820 -1	16. 84	2. 195520	72. 052	12. 78	. 4232	23. 67	4.820	4. 910	. 9022 -1	. 3735 -1
4. 53	3329 -2		. 1959	4. 418	. 4781 -1	16. 99	2. 196473	72. 162	12. 75	. 4230	23. 77	4.824	4. 928	. 8950 -1	. 3719 -1
4. 54	3288 -2		. 1952	4. 428	. 4743 -1	17. 13	2. 197420	72. 271	12. 73	. 4228	23. 88	4.829	4. 946	. 8878 -1	. 3703 -1
4. 55	. 3247 -2	. 1669 -1	. 1945	4. 439	.4706 -1	17. 28	2. 198363	72. 380	12. 70	. 4226	23. 99	4. 833	4. 963	.8806 -1	. 3687 -1
4. 56	. 3207 -2	. 1654 -1	. 1938	4. 449	.4668 -1	17. 42	2. 199300	72. 489	12. 67	. 4224	24. 09	4. 837	4. 981	.8735 -1	. 3671 -1
4. 57	. 3168 -2	. 1640 -1	. 1932	4. 459	.4631 -1	17. 57	2. 200233	72. 597	12. 64	. 4222	24. 20	4. 841	4. 999	.8665 -1	. 3656 -1
4. 58	. 3129 -2	. 1625 -1	. 1925	4. 469	.4594 -1	17. 72	2. 201160	72. 705	12. 61	. 4220	24. 31	4. 845	5. 017	.8596 -1	. 3640 -1
4. 59	. 3090 -2	. 1611 -1	. 1918	4. 480	.4558 -1	17. 87	2. 202083	72. 812	12. 58	. 4219	24. 41	4. 849	5. 034	.8527 -1	. 3624 -1
4. 60	.3053 -2	. 1597 -1	. 1911	4. 490	.4522 -1	18. 02	2. 203000	72. 919	12. 56	. 4217	24. 52	4. 853	5, 052	.8459 -1	. 3609 -1
4. 61	.3015 -2	. 1583 -1	. 1905	4. 500	.4486 -1	18. 17	2. 203913	73. 026	12. 53	. 4215	24. 63	4. 857	5, 070	.8391 -1	. 3593 -1
4. 62	.2978 -2	. 1569 -1	. 1898	4. 510	.4450 -1	18. 32	2. 204822	73. 132	12. 50	. 4213	24. 74	4. 861	5, 088	.8324 -1	. 3578 -1
4. 63	.2942 -2	. 1556 -1	. 1891	4. 521	.4415 -1	18. 48	2. 205725	73. 238	12. 47	. 4211	24. 84	4. 865	5, 106	.8257 -1	. 3563 -1
4. 64	.2906 -2	. 1542 -1	. 1885	4. 531	.4380 -1	18. 63	2. 206624	73. 344	12. 45	. 4210	24. 95	4. 869	5, 124	.8192 -1	. 3548 -1
4. 65	. 2871 -2	. 1529 -1	. 1878	4. 541	.4345 -1	18. 79	2. 207518	73. 449	12. 42	. 4208	25. 06	4, 873	5. 143	.8126 -1	. 3533 -1
4. 66	. 2836 -2	. 1515 -1	. 1872	4. 551	.4311 -1	18. 94	2. 208407	73. 554	12. 39	. 4206	25. 17	4, 877	5. 160	.8062 -1	. 3518 -1
4. 67	. 2802 -2	. 1502 -1	. 1865	4. 562	.4277 -1	19. 10	2. 209291	73. 659	12. 37	. 4204	25. 28	4, 881	5. 179	.7998 -1	. 3503 -1
4. 68	. 2768 -2	. 1489 -1	. 1859	4. 572	.4243 -1	19. 26	2. 210171	73. 763	12. 34	. 4203	25. 39	4, 885	5. 197	.7934 -1	. 3488 -1
4. 69	. 2734 -2	. 1476 -1	. 1852	4. 582	.4210 -1	19. 42	2. 211047	73. 867	12. 31	. 4201	25. 50	4, 889	5. 215	.7871 -1	. 3474 -1
4. 70	. 2701 -2	.1464 -1	. 1846	4. 592	.4177 -1	19. 58	2. 211918	73 970	12. 28	. 4199	25. 61	4. 893	5. 233	. 7809 -1	. 3459 -1
4. 71	. 2669 -2	.1451 -1	. 1839	4. 603	.4144 -1	19. 75	2. 212784	74. 073	12. 26	. 4197	25. 71	4. 896	5. 252	. 7747 -1	. 3445 -1
4. 72	. 2637 -2	.1438 -1	. 1833	4. 613	.4112 -1	19. 91	2. 213646	74. 176	12. 23	. 4196	25. 82	4. 900	5. 270	. 7685 -1	. 3431 -1
4. 73	. 2605 -2	.1426 -1	. 1827	4. 623	.4079 -1	20. 07	2. 214503	74. 279	12. 21	. 4194	25. 94	4. 904	5. 289	. 7625 -1	. 3416 -1
4. 74	. 2573 -2	.1414 -1	. 1820	4. 633	.4047 -1	20. 24	2. 215356	74. 381	12. 18	. 4192	26. 05	4. 908	5. 307	. 7564 -1	. 3402 -1
4. 75	. 2543 -2	.1402 -1	. 1814	4. 644	. 4016 -1	20. 41	2. 216205	74. 483	12. 15	.4191	26. 16	4. 912	5, 325	. 7505 -1	3388 -1
4. 76	. 2512 -2	.1390 -1	. 1808	4. 654	. 3984 -1	20. 58	2. 217049	74. 584	12. 13	.4189	26. 27	4. 915	5, 344	. 7445 -1	3374 -1
4. 77	. 2482 -2	.1378 -1	. 1802	4. 664	. 3953 -1	20. 75	2. 217889	74. 685	12. 10	.4187	26. 38	4. 919	5, 363	. 7387 -1	3360 -1
4. 78	. 2452 -2	.1366 -1	. 1795	4. 674	. 3922 -1	20. 92	2. 218725	74. 786	12. 08	.4186	26. 49	4. 923	5, 381	. 7329 -1	3346 -1
4. 79	. 2423 -2	.1354 -1	. 1789	4. 684	. 3892 -1	21. 09	2. 219556	74. 886	12. 05	.4184	26. 60	4. 926	5, 400	. 7271 -1	3333 -1
4. 80	. 2394 -2	. 1343 -1	. 1783	4. 695	.3862 -1	21. 26	2. 220383	74. 986	12.03	.4183	26. 71	4. 930	5. 418	. 7214 -1	. 3319 -1
4. 81	. 2366 -2	. 1331 -1	. 1777	4. 705	.3832 -1	21. 44	2. 221206	75. 086	12.00	.4181	26. 83	4. 934	5. 437	. 7157 -1	. 3305 -1
4. 82	. 2338 -2	. 1320 -1	. 1771	4. 715	.3802 -1	21. 61	2. 222024	75. 186	11.97	.4179	26. 94	4. 937	5. 456	. 7101 -1	. 3292 -1
4. 83	. 2310 -2	. 1309 -1	. 1765	4. 725	.3772 -1	21. 79	2. 222838	75. 285	11.95	.4178	27. 05	4. 941	5. 475	. 7046 -1	. 3278 -1
4. 84	. 2283 -2	. 1298 -1	. 1759	4. 736	.3743 -1	21. 97	2. 223649	75. 383	11.92	.4176	27. 16	4. 945	5. 494	. 6991 -1	. 3265 -1

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## TABLE II.—SUPERSONIC FLOW—Continued

$egin{array}{c} M \  ext{or} \ M_1 \end{array}$	$\frac{p}{p_i}$	$\frac{\rho}{\rho_t}$	$rac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	Ψ	μ	$M_2$	$rac{p_2}{p_1}$	<u>ρ2</u> ρ1	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{\ell_2}}$
4. 85	. 2255 -2	. 1287 -1	. 1753	4. 746	.3714 -1	22. 15	2. 224455	75. 482	11. 90	.4175	27. 28	4. 948	5. 512	. 6936 -1	. 3252 -1
4. 86	. 2229 -2	. 1276 -1	. 1747	4. 756	.3685 -1	22. 33	2. 225257	75. 580	11. 87	.4173	27. 39	4. 952	5. 531	. 6882 -1	. 3239 -1
4. 87	. 2202 -2	. 1265 -1	. 1741	4. 766	.3657 -1	22. 51	2. 226055	75. 678	11. 85	.4172	27. 50	4. 955	5. 550	. 6828 -1	. 3226 -1
4. 88	. 2177 -2	. 1254 -1	. 1735	4. 776	.3628 -1	22. 70	2. 226848	75. 775	11. 83	.4170	27. 62	4. 959	5. 569	. 6775 -1	. 3213 -1
4. 89	. 2151 -2	. 1244 -1	. 1729	4. 787	.3600 -1	22. 88	2. 227638	75. 872	11. 80	.4169	27. 73	4. 962	5. 588	. 6722 -1	. 3200 -1
4. 90 4. 91 4. 92 4. 93 4. 94	. 2126 -2 . 2101 -2 . 2076 -2 . 2052 -2 . 2028 -2	$\begin{array}{ccccc} .1233 & ^{-1}\\ .1223 & ^{-1}\\ .1213 & ^{-1}\\ .1202 & ^{-1}\\ .1192 & ^{-1}\\ \end{array}$	. 1724 . 1718 . 1712 . 1706 . 1700	4. 797 4. 807 4. 817 4. 828 4. 838	.3573 -1 .3545 -1 .3518 -1 .3491 -1 .3464 -1	23. 07 23. 25 23. 44 23. 63 23. 82	2. 228424 2. 229206 2. 229984 2. 230758 2. 231528	75. 969 76. 066 76. 162 76. 258 76. 353	11. 78 11. 75 11. 73 11. 70 11. 68	.4167 .4165 .4164 .4163 .4161	27. 85 27. 96 28. 07 28. 19 28. 30	4. 966 4. 969 4. 973 4. 976 4. 980	5. 607 5. 626 5. 646 5. 665 5. 684	. 6670 -1 . 6618 -1 . 6567 -1 . 6516 -1 . 6465 -1	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
4. 95 4. 96 4. 97 4. 98 4. 99	$\begin{array}{ccccc} .2004 & -2 \\ .1981 & -2 \\ .1957 & -2 \\ .1935 & -2 \\ .1912 & -2 \\ \end{array}$	.1182 -1 .1173 -1 .1163 -1 .1153 -1 .1144 -1	. 1695 . 1689 . 1683 . 1678 . 1672	4. 848 4. 858 4. 868 4. 879 4. 889	.3437 - 1 $.3411 - 1$ $.3385 - 1$ $.3359 - 1$ $.3333 - 1$	24. 02 24. 21 24. 41 24. 60 24. 80	2. 232294 2. 233056 2. 233815 2. 234570 2. 235321	76. 449 76. 544 76. 638 76. 732 76. 826	11. 66 11. 63 11. 61 11. 58 11. 56	. 4160 . 4158 . 4157 . 4155 . 4154	28. 42 28. 54 28. 65 28. 77 28. 88	4. 983 4. 987 4. 990 4. 993 4. 997	5. 703 5. 723 5. 742 5. 761 5. 781	. 6415 -1 . 6366 -1 . 6317 -1 . 6268 -1 . 6220 -1	$ \begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$
5. 00	.1890 -2	.1134 -1	. 1667	4, 899	.3308 -1	25. 00	2. 236068	76. 920	11. 54	.4152	29. 00	5, 000	5, 800	.6172 -1	.3062 -1
5. 01	.1868 -2	.1125 -1	. 1661	4, 909	.3282 -1	25. 20	2. 236811	77. 013	11. 51	.4151	29. 12	5, 003	5, 820	.6124 -1	.3051 -1
5. 02	.1847 -2	.1115 -1	. 1656	4, 919	.3257 -1	25. 40	2. 237551	77. 106	11. 49	.4149	29. 23	5, 007	5, 839	.6077 -1	.3039 -1
5. 03	.1825 -2	.1106 -1	. 1650	4, 930	.3233 -1	25. 61	2. 238287	77. 199	11. 47	.4148	29. 35	5, 010	5, 859	.6030 -1	.3027 -1
5. 04	.1804 -2	.1097 -1	. 1645	4, 940	.3208 -1	25. 81	2. 239020	77. 291	11. 44	.4147	29. 47	5, 013	5, 878	.5984 -1	.3015 -1
5. 05	. 1783 -2	. 1088 -1	. 1639	4. 950	.3184 -1	26. 02	2. 239749	77. 385	11. 42	. 4145	29. 59	5. 016	5. 898	.5938 -1	.3003 -t
5. 06	. 1763 -2	. 1079 -1	. 1634	4. 960	.3159 -1	26. 22	2. 240474	77. 477	11. 40	. 4144	29. 70	5. 020	5. 918	.5893 -1	.2991 -t
5. 07	. 1742 -2	. 1070 -1	. 1628	4. 970	.3135 -1	26. 43	2. 241195	77. 568	11. 38	. 4142	29. 82	5. 023	5. 937	.5848 -1	.2980 -t
5. 08	. 1722 -2	. 1061 -1	. 1623	4. 981	.3112 -1	26. 64	2. 241914	77. 660	11. 35	. 4141	29. 94	5. 026	5. 957	.5803 -1	.2968 -t
5. 09	. 1703 -2	. 1053 -1	. 1618	4. 991	.3088 -1	26. 86	2. 242628	77. 751	11. 33	. 4140	30. 06	5. 029	5. 977	.5759 -1	.2957 -t
5. 10	. 1683 -2	. 1044 -1	. 1612	5. 001	.3065 -1	27. 07	2. 243339	77. 841	11. 31	. 4138	30. 18	5. 033	5. 997	.5715 -1	. 2945 -t
5. 11	. 1664 -2	. 1035 -1	. 1607	5. 011	.3042 -1	27. 28	2. 244047	77. 931	11. 29	. 4137	30. 30	5. 036	6. 016	.5672 -1	. 2934 -1
5. 12	. 1645 -2	. 1027 -1	. 1602	5. 021	.3019 -1	27. 50	2. 244751	78. 021	11. 26	. 4136	30. 42	5. 039	6. 036	.5628 -1	. 2923 -1
5. 13	. 1626 -2	. 1019 -1	. 1597	5. 032	.2996 -1	27. 72	2. 245451	78. 111	11. 24	. 4134	30. 54	5. 042	6. 056	.5586 -1	. 2911 -1
5. 14	. 1608 -2	. 1010 -1	. 1591	5. 042	.2973 -1	27. 94	2. 246148	78. 201	11. 22	. 4133	30. 66	5. 045	6. 076	.5543 -1	. 2900 -1
5. 15	. 1589 -2	. 1002 -1	.1586	5. 052	. 2951 -1	28. 16	2. 246842	78. 290	11. 20	. 4132	30. 78	5. 048	6. 096	. 5501 -1	. 2889 -1
5. 16	. 1571 -2	. 9939 -2	.1581	5. 062	. 2929 -1	28. 38	2. 247532	78. 379	11. 18	. 4130	30. 90	5. 051	6. 117	. 5460 -1	. 2878 -1
5. 17	. 1553 -2	. 9858 -2	.1576	5. 072	. 2907 -1	28. 60	2. 248219	78. 468	11. 15	. 4129	31. 02	5. 054	6. 137	. 5418 -1	. 2867 -1
5. 18	. 1536 -2	. 9778 -2	.1571	5. 083	. 2885 -1	28. 83	2. 248903	78. 556	11. 13	. 4128	31. 14	5. 058	6. 157	. 5377 -1	. 2856 -1
5. 19	. 1518 -2	. 9699 -2	,1566	5. 093	. 2863 -1	29. 06	2. 249583	78. 645	11. 11	. 4126	31. 26	5. 061	6. 177	. 5337 -1	. 2845 -1
5. 20	. 1501 -2	. 9620 -2	. 1561	5. 103	. 2842 -1	29. 28	2. 250260	78. 733	11. 09	. 4125	31. 38	5. 064	6. 197	.5297 -1	. 2834 -1
5. 21	.1484 -2	. 9543 -2	. 1555	5. 113	. 2821 -1	29. 51	2. 250934	78. 820	11. 07	. 4124	31. 50	5. 067	6. 217	.5257 -1	. 2824 -1
5. 22	.1468 -2	. 9466 -2	. 1550	5. 123	. 2799 -1	29. 74	2. 251604	78. 908	11. 04	. 4123	31. 62	5. 070	6. 238	.5217 -1	. 2813 -1
5. 23	.1451 -2	. 9389 -2	. 1545	5. 134	. 2778 -1	29. 98	2. 252271	78. 995	11. 02	. 4121	31. 75	5. 073	6. 258	.5178 -1	. 2803 -1
5. 24	.1435 -2	. 9314 -2	. 1540	5. 144	. 2758 -1	30. 21	2. 252935	79. 081	11. 00	. 4120	31. 87	5. 076	6. 278	.5139 -1	. 2792 -1
5. 25	.1419 -2	. 9239 -2	. 1536	5. 154	. 2737 -1	30. 45	2. 253596	79. 167	10. 98	. 4119	31. 99	5. 079	6. 299	.5100 -1	. 2782 -1
5. 26	.1403 -2	. 9165 -2	. 1531	5. 164	. 2717 -1	30. 68	2. 254254	79. 254	10. 96	. 4118	32. 11	5. 082	6. 319	.5062 -1	. 2771 -1
5. 27	.1387 -2	. 9092 -2	. 1526	5. 174	. 2697 -1	30. 92	2. 254908	79. 340	10. 94	. 4116	32. 24	5. 085	6. 340	.5024 -1	. 2761 -1
5. 28	.1372 -2	. 9019 -2	. 1521	5. 184	. 2677 -1	31. 16	2. 255559	79. 426	10. 92	. 4115	32. 36	5. 088	6. 360	.4987 -1	. 2750 -1
5. 29	.1356 -2	. 8947 -2	. 1516	5. 195	. 2657 -1	31. 41	2. 256207	79. 511	10. 90	. 4114	32. 48	5. 090	6. 381	.4950 -1	. 2740 -1
5. 30	. 1341 -2	.8875 -2	. 1511	5. 205	. 2637 -1	31. 65	2. 256852	79. 597	10. 88	. 4113	32. 61	5. 093	6. 401	.4913 -1	. 2730 -1
5. 31	. 1326 -2	.8805 -2	. 1506	5. 215	. 2617 -1	31. 89	2. 257494	79. 681	10. 86	. 4112	32. 73	5. 096	6. 422	.4876 -1	. 2720 -1
5. 32	. 1311 -2	.8734 -2	. 1501	5. 225	. 2598 -1	32. 14	2. 258133	79. 765	10. 83	. 4110	32. 85	5. 099	6. 443	.4840 -1	. 2710 -1
5. 33	. 1297 -2	.8665 -2	. 1497	5. 235	. 2579 -1	32. 39	2. 258769	79. 850	10. 81	. 4109	32. 98	5. 102	6. 464	.4804 -1	. 2700 -1
5. 34	. 1282 -2	.8596 -2	. 1492	5. 246	. 2560 -1	32. 64	2. 259401	79. 934	10. 79	. 4108	33. 10	5. 105	6. 484	.4768 -1	. 2690 -1
5. 35	. 1268 -2	.8528 -2	. 1487	5. 256	. 2541 -1	32. 89	2. 260031	80. 018	10. 77	. 4107	33. 23	5. 108	6. 505	. 4733 -1	. 2680 -1
5. 36	. 1254 -2	.8461 -2	. 1482	5. 266	. 2522 -1	33. 14	2. 260658	80. 101	10. 75	. 4106	33. 35	5. 111	6. 526	. 4697 -1	. 2670 -1
5. 37	. 1240 -2	.8394 -2	. 1478	5. 276	. 2504 -1	33. 40	2. 261281	80. 185	10. 73	. 4104	33. 48	5. 113	6. 547	. 4663 -1	. 2660 -1
5. 38	. 1227 -2	.8327 -2	. 1473	5. 286	. 2485 -1	33. 66	2. 261902	80. 268	10. 71	. 4103	33. 60	5. 116	6. 568	. 4628 -1	. 2650 -1
5. 39	. 1213 -2	.8262 -2	. 1468	5. 296	. 2467 -1	33. 91	2. 262520	80. 351	10. 69	. 4102	33. 73	5. 119	6. 589	. 4594 -1	. 2641 -1
5. 40	. 1200 -2	.8197 -2	. 1464	5. 307	. 2449 -1	34. 17	2. 263135	80. 434	10. 67	. 4101	33. 85	5. 122	6. 610	.4560 -1	. 2631 -1
5. 41	. 1187 -2	.8132 -2	. 1459	5. 317	. 2431 -1	34. 44	2. 263747	80. 515	10. 65	. 4100	33. 98	5. 125	6. 631	.4526 -1	. 2621 -1
5. 42	. 1174 -2	.8068 -2	. 1454	5. 327	. 2413 -1	34. 70	2. 264356	80. 597	10. 63	. 4099	34. 11	5. 127	6. 652	.4493 -1	. 2612 -1
5. 43	. 1161 -2	.8005 -2	. 1450	5. 337	. 2395 -1	34. 97	2. 264962	80. 680	10. 61	. 4098	34. 23	5. 130	6. 673	.4460 -1	. 2602 -1
5. 44	. 1148 -2	.7942 -2	. 1445	5. 347	. 2378 -1	35. 23	2. 265566	80. 760	10. 59	. 4096	34. 36	5. 133	6. 694	.4427 -1	. 2593 -1
5. 45	.1135 -2	. 7880 -2	. 1441	5. 357	$\begin{array}{c} .\ 2361 & -1 \\ .\ 2344 & -1 \\ .\ 2326 & -1 \\ .\ 2309 & -1 \\ .\ 2293 & -1 \\ \end{array}$	35. 50	2. 266166	80. 842	10. 57	. 4095	34. 49	5. 136	6. 715	.4395 -1	. 2583 -1
5. 46	.1123 -2	. 7818 -2	. 1436	5. 368		35. 77	2. 266764	80. 923	10. 55	. 4094	34. 61	5. 138	6. 737	.4362 -1	. 2574 -1
5. 47	.1111 -2	. 7757 -2	. 1432	5. 378		36. 04	2. 267359	81. 004	10. 53	. 4093	34. 74	5. 141	6. 758	.4330 -1	. 2565 -1
5. 48	.1099 -2	. 7697 -2	. 1427	5. 388		36. 32	2. 267951	81. 084	10. 51	. 4092	34. 87	5. 144	6. 779	.4299 -1	. 2556 -1
5. 49	.1087 -2	. 7637 -2	. 1423	5. 398		36. 59	2. 268540	81. 165	10. 50	. 4091	35. 00	5. 146	6. 800	.4267 -1	. 2546 -1
5. 50 5. 51 5. 52 5. 53 5. 54	$\begin{array}{cccc} .1075 & -2 \\ .1063 & -2 \\ .1052 & -2 \\ .1040 & -2 \\ .1029 & -2 \\ \end{array}$	.7578 -2 .7519 -2 .7460 -2 .7403 -2 .7345 -2	. 1418 . 1414 . 1410 . 1405 . 1401	5. 408 5. 418 5. 429 5. 439 5. 449	$\begin{array}{ccccc} .\ 2276 & -1 \\ .\ 2260 & -1 \\ .\ 2243 & -1 \\ .\ 2227 & -1 \\ .\ 2211 & -1 \\ \end{array}$	36. 87 37. 15 37. 43 37. 71 38. 00	2. 269127 2. 269711 2. 270292 2. 270870 2. 271446	81. 245 81. 324 81. 404 81. 484 81. 563	10. 48 10. 46 10. 44 10. 42 10. 40	. 4090 . 4089 . 4088 . 4086 . 4085	35. 13 35. 25 35. 38 35. 51 35. 64	5. 149 5. 152 5. 154 5. 157 5. 159	6. 822 6. 843 6. 865 6. 886 6. 908	.4236 -1 .4205 -1 .4175 -1 .4144 -1 .4114 -1	. 2537 -1 . 2528 -1 . 2519 -1 . 2510 -1 . 2501 -1
5. 55	. 1018 -2	$\begin{array}{cccc} .7289 & ^{-2}\\ .7232 & ^{-2}\\ .7177 & ^{-2}\\ .7121 & ^{-2}\\ .7067 & ^{-2}\\ \end{array}$	. 1397	5. 459	. 2195 -1	38. 28	2. 272019	81. 641	10. 38	. 4084	35. 77	5. 162	6. 929	.4084 -1	. 2492 -1
5. 56	. 1007 -2		. 1392	5. 469	. 2179 -1	38. 57	2. 272589	81. 720	10. 36	. 4083	35. 90	5. 165	6. 951	.4054 -1	. 2483 -1
5. 57	. 9961 -3		. 1388	5. 479	. 2163 -1	38. 86	2. 273157	81. 798	10. 34	. 4082	36. 03	5. 167	6. 973	.4025 -1	. 2475 -1
5. 58	. 9853 -3		. 1384	5. 490	. 2148 -1	39. 15	2. 273722	81. 876	10. 32	. 4081	36. 16	5. 170	6. 994	.3996 -1	. 2466 -1
5. 59	. 9748 -3		. 1379	5. 500	. 2132 -1	39. 44	2. 274285	81. 955	10. 31	. 4080	36. 29	5. 172	7. 016	.3967 -1	. 2457 -1
5. 60	. 9643 -3	. 7012 -2	. 1375	5. 510	$\begin{array}{c} .2117 & ^{-1} \\ .2102 & ^{-1} \\ .2087 & ^{-1} \\ .2072 & ^{-1} \\ .2057 & ^{-1} \\ \end{array}$	39. 74	2. 274844	82. 032	10. 29	. 4079	36. 42	5. 175	7. 038	.3938 -1	. 2449 -1
5. 61	. 9540 -3	. 6959 -2	. 1371	5. 520		40. 04	2. 275402	82. 109	10. 27	. 4078	36. 55	5. 177	7. 060	.3910 -1	. 2440 -1
5. 62	. 9438 -3	. 6905 -2	. 1367	5. 530		40. 34	2. 275957	82. 187	10. 25	. 4077	36. 68	5. 180	7. 082	.3882 -1	. 2431 -1
5. 63	. 9337 -3	. 6853 -2	. 1363	5. 540		40. 64	2. 276509	82. 263	10. 23	. 4076	36. 81	5. 182	7. 103	.3854 -1	. 2423 -1
5. 64	. 9237 -3	. 6800 -2	. 1358	5. 551		40. 94	2. 277058	82. 340	10. 21	. 4075	36. 94	5. 185	7. 125	.3826 -1	. 2414 -1
5. 65	.9139 -3	. 6748 -2	. 1354	5. 561	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	41. 25	2. 277606	82. 417	10. 20	. 4074	37. 08	5. 187	7. 147	.3798 -1	. 2406 -1
5. 66	.9041 -3	. 6697 -2	. 1350	5. 571		41. 55	2. 278150	82. 493	10. 18	. 4073	37. 21	5. 190	7. 169	.3771 -1	. 2397 -1
5. 67	.8945 -3	. 6646 -2	. 1346	5. 581		41. 86	2. 278692	82. 569	10. 16	. 4072	37. 34	5. 192	7. 191	.3744 -1	. 2389 -1
5. 68	.8850 -3	. 6596 -2	. 1342	5. 591		42. 17	2. 279232	82. 645	10. 14	. 4071	37. 47	5. 195	7. 213	.3717 -1	. 2381 -1
5. 69	.8756 -3	. 6545 -2	. 1338	5. 601		42. 48	2. 279769	82. 720	10. 12	. 4070	37. 61	5. 197	7. 236	.3691 -1	. 2372 -1
5. 70	. 8663 -3	. 6496 -2	. 1334	5. 612	. 1970 -1	42. 80	2. 280304	82. 795	10. 10	. 4069	37. 74	5. 200	7. 258	. 3664 -1	. 2364 -1
5. 71	. 8572 -3	. 6447 -2	. 1330	5. 622	. 1956 -1	43. 11	2. 280836	82. 871	10. 09	. 4068	37. 87	5. 202	7. 280	. 3638 -1	. 2356 -1
5. 72	. 8481 -3	. 6398 -2	. 1326	5. 632	. 1942 -1	43. 43	2. 281366	82. 946	10. 07	. 4067	38. 00	5. 205	7. 302	. 3612 -1	. 2348 -1
5. 73	. 8392 -3	. 6350 -2	. 1322	5. 642	. 1929 -1	43. 75	2. 281894	83. 020	10. 05	. 4066	38. 14	5. 207	7. 324	. 3586 -1	. 2340 -1
5. 74	. 8303 -3	. 6302 -2	. 1318	5. 652	. 1915 -1	44. 07	2. 282419	83. 095	10. 03	. 4065	38. 27	5. 209	7. 347	. 3561 -1	. 2332 -1

## EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

### TABLE II.—SUPERSONIC FLOW—Continued

	<del> </del>						$\gamma = i/3$	I	1	1	1		1	1	1
$egin{array}{c} M \  ext{or} \ M_1 \end{array}$	$\frac{p}{p_t}$	$\frac{ ho}{ ho \iota}$	$rac{T}{T_t}$	β	$\frac{q}{p_i}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{i_2}}$
5. 75	. 8216 -3	. 6254 -2	. 1314	5. 662	. 1902 -1	44. 40	2. 282942	83. 169	10. 02	. 4064	38. 41	5. 212	7. 369	. 3536 -1	. 2324 -1
5. 76	. 8130 -3	. 6207 -2	. 1310	5. 673	. 1888 -1	44. 72	2. 283462	83. 243	9. 998	. 4063	38. 54	5. 214	7. 392	. 3510 -1	. 2316 -1
5. 77	. 8044 -3	. 6161 -2	. 1306	5. 683	. 1875 -1	45. 05	2. 283980	83. 317	9. 980	. 4062	38. 68	5. 217	7. 414	. 3486 -1	. 2308 -1
5. 78	. 7960 -3	. 6114 -2	. 1302	5. 693	. 1862 -1	45. 38	2. 284496	83. 391	9. 963	. 4061	38. 81	5. 219	7. 436	. 3461 -1	. 2300 -1
5. 79	. 7876 -3	. 6069 -2	. 1298	5. 703	. 1848 -1	45. 72	2. 285009	83. 463	9. 946	. 4060	38. 94	5. 221	7. 459	. 3436 -1	. 2292 -1
5. 80 5. 81 5. 82 5. 83 5. 84	.7794 -3 .7713 -3 .7632 -3 .7553 -3 .7474 -3	$\begin{array}{cccc} .6023 & -2 \\ .5978 & -2 \\ .5934 & -2 \\ .5889 & -2 \\ .5846 & -2 \end{array}$	. 1294 . 1290 . 1286 . 1282 . 1279	5. 713 5. 723 5. 733 5. 744 5. 754	. 1835 -1 . 1823 -1 . 1810 -1 . 1797 -1 . 1784 -1	46. 05 46. 39 46. 72 47. 07 47. 41	2. 285520 2. 286029 2. 286535 2. 287040 2. 287542	83. 537 83. 609 83. 683 83. 755 83. 827	9. 928 9. 911 9. 894 9. 877 9. 860	. 4059 . 4059 . 4058 . 4057 . 4056	39. 08 39. 22 39. 35 39. 49 39. 62	5. 224 5. 226 5. 228 5. 231 5. 233	7. 481 7. 504 7. 527 7. 549 7. 572	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 2284 -1 . 2277 -1 . 2269 -1 . 2261 -1 . 2254 -1
5. 85	.7396 -3	. 5802 -2	. 1275	5. 764	. 1772 -1	47. 75	2. 288041	83. 899	9. 842	. 4055	39. 76	5. 235	7. 595	. 3293 -1	. 2246 -1
5. 86	.7320 -3	. 5759 -2	. 1271	5. 774	. 1760 -1	48. 10	2. 288539	83. 971	9. 826	. 4054	39. 90	5. 237	7. 618	. 3270 -1	. 2238 -1
5. 87	.7244 -3	. 5716 -2	. 1267	5. 784	. 1747 -1	48. 45	2. 289034	84. 042	9. 809	. 4053	40. 03	5. 240	7. 640	. 3247 -1	. 2231 -1
5. 88	.7169 -3	. 5674 -2	. 1263	5. 794	. 1735 -1	48. 80	2. 289527	84. 114	9. 792	. 4052	40. 17	5. 242	7. 663	. 3225 -1	. 2223 -1
5. 89	.7095 -3	. 5632 -2	. 1260	5. 804	. 1723 -1	49. 15	2. 290018	84. 185	9. 775	. 4051	40. 31	5. 244	7. 686	. 3202 -1	. 2216 -1
5. 90	. 7021 -3	. 5590 -2	. 1256	5. 815	.1711 -1	49. 51	2. 290507	84. 257	9. 758	. 4050	40. 45	5. 246	7. 709	. 3180 -1	. 2208 -1
5. 91	. 6949 -3	. 5549 -2	. 1252	5. 825	.1699 -1	49. 86	2. 290993	84. 327	9. 742	. 4049	40. 58	5. 249	7. 732	. 3157 -1	. 2201 -1
5. 92	. 6877 -3	. 5508 -2	. 1249	5. 835	.1687 -1	50. 22	2. 291477	84. 398	9. 725	. 4049	40. 72	5. 251	7. 755	. 3135 -1	. 2194 -1
5. 93	. 6807 -3	. 5468 -2	. 1245	5. 845	.1676 -1	50. 59	2. 291960	84. 468	9. 708	. 4048	40. 86	5. 253	7. 778	. 3113 -1	. 2186 -1
5. 94	. 6737 -3	. 5428 -2	. 1241	5. 855	.1664 -1	50. 95	2. 292440	84. 539	9. 692	. 4047	41. 00	5. 255	7. 801	. 3092 -1	. 2179 -1
5. 95	. 6668 -3	. 5388 -2	. 1238	5. 865	. 1652 -1	51. 32	2. 292918	84. 609	9. 675	. 4046	41. 14	5. 257	7. 824	. 3070 -1	$\begin{array}{ccccc} .\ 2172 & -1 \\ .\ 2165 & -1 \\ .\ 2157 & -1 \\ .\ 2150 & -1 \\ .\ 2143 & -1 \\ \end{array}$
5. 96	. 6599 -3	. 5348 -2	. 1234	5. 876	. 1641 -1	51. 68	2. 293394	84. 679	9. 659	. 4045	41. 28	5. 260	7. 847	. 3049 -1	
5. 97	. 6532 -3	. 5309 -2	. 1230	5. 886	. 1630 -1	52. 05	2. 293867	84. 748	9. 643	. 4044	41. 41	5. 262	7. 871	. 3028 -1	
5. 98	. 6465 -3	. 5270 -2	. 1227	5. 896	. 1618 -1	52. 43	2. 294339	84. 817	9. 626	. 4043	41. 55	5. 264	7. 894	. 3007 -1	
5. 99	. 6399 -3	. 5232 -2	. 1223	5. 906	. 1607 -1	52. 80	2. 294809	84. 887	9. 610	. 4042	41. 69	5. 266	7. 917	. 2986 -1	
6. 00	.6334 -3	.5194 -2	. 1220	5. 916	.1596 -1	53. 18	2. 295276	84. 955	9. 594	. 4042	41. 83	5. 268	7. 941	. 2965 -1	$\begin{array}{ccccc} .\ 2136 & ^{-1} \\ .\ 2129 & ^{-1} \\ .\ 2122 & ^{-1} \\ .\ 2115 & ^{-1} \\ .\ 2108 & ^{-1} \\ \end{array}$
6. 01	.6269 -3	.5156 -2	. 1216	5. 926	.1585 -1	53. 56	2. 295742	85. 025	9. 578	. 4041	41. 97	5. 270	7. 964	. 2945 -1	
6. 02	.6205 -3	.5118 -2	. 1212	5. 936	.1574 -1	53. 94	2. 296205	85. 093	9. 562	. 4040	42. 11	5. 273	7. 987	. 2924 -1	
6. 03	.6142 -3	.5081 -2	. 1209	5. 947	.1563 -1	54. 32	2. 296667	85. 162	9. 546	. 4039	42. 25	5. 275	8. 011	. 2904 -1	
6. 04	.6080 -3	.5044 -2	. 1205	5. 957	.1553 -1	54. 71	2. 297126	85. 230	9. 530	. 4038	42. 40	5. 277	8. 034	. 2884 -1	
6. 05	.6018 -3	. 5008 -2	. 1202	5. 967	. 1542 -1	55. 10	2. 297583	85, 297	9. 514	. 4037	42. 54	5. 279	8. 058	. 2864 -1	. 2101 -1
6. 06	.5957 -3	. 4971 -2	. 1198	5. 977	. 1531 -1	55. 49	2. 298039	85, 366	9. 498	. 4037	42. 68	5. 281	8. 081	. 2844 -1	. 2094 -1
6. 07	.5897 -3	. 4935 -2	. 1195	5. 987	. 1521 -1	55. 88	2. 298492	85, 433	9. 482	. 4036	42. 82	5. 283	8. 105	. 2825 -1	. 2088 -1
6. 08	.5838 -3	. 4900 -2	. 1191	5. 997	. 1511 -1	56. 28	2. 298944	85, 500	9. 467	. 4035	42. 96	5. 285	8. 129	. 2806 -1	. 2081 -1
6. 09	.5779 -3	. 4864 -2	. 1188	6. 007	. 1500 -1	56. 68	2. 299393	85, 568	9. 451	. 4034	43. 10	5. 287	8. 152	. 2786 -1	. 2074 -1
6. 10 6. 11 6. 12 6. 13 6. 14	. 5721 -3 . 5663 -3 . 5606 -3 . 5550 -3 . 5494 -3	. 4829 -2 . 4795 -2 . 4760 -2 . 4726 -2 . 4692 -2	. 1185 . 1181 . 1178 . 1174 . 1171	6. 017 6. 028 6. 038 6. 048 6. 058	$\begin{array}{cccc} .1490 & -1 \\ .1480 & -1 \\ .1470 & -1 \\ .1460 & -1 \\ .1450 & -1 \\ \end{array}$	57. 08 57. 48 57. 88 58. 29 58. 70	2. 299841 2. 300286 2. 300730 2. 301172 2. 301612	85. 635 85. 702 85. 768 85. 834 85. 901	9. 435 9. 420 9. 404 9. 389 9. 373	. 4033 . 4033 . 4032 . 4031 . 4030	43. 25 43. 39 43. 53 43. 67 43. 82	5. 289 5. 291 5. 293 5. 295 5. 297	8. 176 8. 200 8. 223 8. 247 8. 271	$\begin{array}{ccccc} .2767 & -1 \\ .2748 & -1 \\ .2730 & -1 \\ .2711 & -1 \\ .2692 & -1 \\ \end{array}$	. 2067 -1 . 2061 -1 . 2054 -1 . 2047 -1 . 2041 -1
6. 15	. 5439 -3	.4658 -2 $.4625 -2$ $.4592 -2$ $.4559 -2$ $.4527 -2$	. 1168	6. 068	.1440 -1	59. 11	2. 302050	85. 967	9. 358	. 4029	43. 96	5. 299	8. 295	. 2674 -1	. 2034 -1
6. 16	. 5385 -3		1164	6. 078	.1430 -1	59. 53	2. 302486	86. 033	9. 343	. 4029	44. 10	5. 301	8. 319	. 2656 -1	. 2028 -1
6. 17	. 5331 -3		. 1161	6. 088	.1421 -1	59. 94	2. 302920	86. 099	9. 327	. 4028	44. 25	5. 303	8. 343	. 2638 -1	. 2021 -1
6. 18	. 5278 -3		. 1158	6. 099	.1411 -1	60. 36	2. 303353	86. 164	9. 312	. 4027	44. 39	5. 305	8. 367	. 2620 -1	. 2015 -1
6. 19	. 5225 -3		. 1154	6. 109	.1402 -1	60. 79	2. 303783	86. 229	9. 297	. 4026	44. 54	5. 307	8. 391	. 2602 -1	. 2008 -1
6. 20	.5173 -3	.4495 -2 $.4463 -2$ $.4431 -2$ $.4400 -2$ $.4369 -2$	.1151	6. 119	.1392 -1	61. 21	2. 304212	86, 295	9. 282	. 4025	44. 68	5. 309	8. 415	. 2584 -1	. 2002 -1
6. 21	.5122 -3		.1148	6. 129	.1383 -1	61. 64	2. 304639	86, 360	9. 267	. 4025	44. 82	5. 311	8. 439	. 2567 -1	. 1995 -1
6. 22	.5071 -3		.1144	6. 139	.1373 -1	62. 07	2. 305064	86, 424	9. 252	. 4024	44. 97	5. 313	8. 464	. 2550 -1	. 1989 -1
6. 23	.5021 -3		.1141	6. 149	.1364 -1	62. 50	2. 305487	86, 490	9. 237	. 4023	45. 12	5. 315	8. 488	. 2532 -1	. 1983 -1
6. 24	.4971 -3		.1138	6. 159	.1355 -1	62. 93	2. 305908	86, 554	9. 222	. 4022	45. 26	5. 317	8. 512	. 2515 -1	. 1977 -1
6. 25	. 4922 -3	. 4338 -2	. 1135	6. 169	.1346 -1	63. 37	2. 306328	86. 618	9. 207	. 4022	45. 41	5. 319	8. 536	. 2498 -1	. 1970 -1
6. 26	. 4874 -3	. 4307 -2	. 1132	6. 180	.1337 -1	63. 81	2. 306746	86. 683	9. 192	. 4021	45. 55	5. 321	8. 561	. 2482 -1	. 1964 -1
6. 27	. 4825 -3	. 4277 -2	. 1128	6. 190	.1328 -1	64. 25	2. 307162	86. 746	9. 177	. 4020	45. 70	5. 323	8. 585	. 2465 -1	. 1958 -1
6. 28	. 4778 -3	. 4246 -2	. 1125	6. 200	.1319 -1	64. 69	2. 307576	86. 810	9. 163	. 4019	45. 84	5. 325	8. 610	. 2448 -1	. 1952 -1
6. 29	. 4731 -3	. 4217 -2	. 1122	6. 210	.1310 -1	65. 14	2. 307989	86. 874	9. 148	. 4019	45. 99	5. 327	8. 634	. 2432 -1	. 1945 -1
6. 30	. 4684 -3	.4187 -2	.1119	6. 220	.1302 -I	65. 59	2. 308400	86. 937	9. 133	. 4018	46. 14	5. 329	8. 658	$\begin{array}{c} .2416 & \cdot 1 \\ .2399 & -1 \\ .2383 & -1 \\ .2367 & -1 \\ .2352 & -1 \\ \end{array}$	. 1939 -1
6. 31	. 4638 -3	.4158 -2	.1116	6. 230	.1293 -I	66. 04	2. 308809	87. 000	9. 119	. 4017	46. 29	5. 331	8. 683		. 1933 -1
6. 32	. 4593 -3	.4128 -2	.1113	6. 240	.1284 -I	66. 50	2. 309216	87. 063	9. 104	. 4016	46. 43	5. 332	8. 708		. 1927 -1
6. 33	. 4548 -3	.4100 -2	.1109	6. 251	.1276 -I	66. 95	2. 309622	87. 126	9. 090	. 4016	46. 58	5. 334	8. 732		. 1921 -1
6. 34	. 4504 -3	.4071 -2	.1106	6. 261	.1267 -I	67. 41	2. 310026	87. 189	9. 075	. 4015	46. 73	5. 336	8. 757		. 1915 -1
6. 35 6. 36 6. 37 6. 38 6. 39	$\begin{array}{ccccc} .4460 & -3 \\ .4416 & -3 \\ .4373 & -3 \\ .4331 & -3 \\ .4288 & -3 \end{array}$	.4042 -2 .4014 -2 .3986 -2 .3958 -2 .3931 -2	. 1103 . 1100 . 1097 . 1094 . 1091	6, 271 6, 281 6, 291 6, 301 6, 311	$\begin{array}{cccc} .1259 & -1 \\ .1250 & -1 \\ .1242 & -1 \\ .1234 & -1 \\ .1226 & -1 \\ \end{array}$	67, 88 68, 34 68, 81 69, 28 69, 75	2. 310428 2. 310828 2. 311227 2. 311625 2. 312020	87. 251 87. 313 87. 376 87. 438 87. 499	9. 061 9. 046 9. 032 9. 018 9. 004	. 4014 . 4014 . 4013 . 4012 . 4011	46. 88 47. 02 47. 17 47. 32 47. 47	5. 338 5. 340 5. 342 5. 344 5. 345	8. 781 8. 806 8. 831 8. 856 8. 881	.2336 -1 .2320 -1 .2305 -1 .2290 -1 .2274 -1	. 1909 — 1 . 1903 — 1 . 1897 — 1 . 1891 — 1 . 1886 — 1
6. 40 6. 41 6. 42 6. 43 6. 44	. 4247 -3 . 4206 -3 . 4165 -3 . 4125 -3 . 4085 -3	$ \begin{array}{rrrr} .3904 & -2 \\ .3877 & -2 \\ .3850 & -2 \\ .3823 & -2 \\ .3797 & -2 \end{array} $	. 1088 . 1085 . 1082 . 1079 . 1076	6. 321 6. 332 6. 342 6. 352 6. 362	.1218 -1 .1210 -1 .1202 -1 .1194 -1 .1186 -1	70. 23 70. 57 71. 19 71. 67 72. 16	2. 312414 2. 312806 2. 313197 2. 313586 2. 313973	87. 561 87. 623 87. 684 87. 745 87. 806	8. 989 8. 975 8. 961 8. 947 8. 933	. 4011 . 4010 . 4009 . 4009 . 4008	47. 62 47. 77 47. 92 48. 07 48. 22	5. 347 5. 349 5. 351 5. 353 5. 354	8. 905 8. 930 8. 955 8. 980 9. 005	$\begin{array}{ccccc} .2259 & -1 \\ .2244 & -1 \\ .2230 & -1 \\ .2215 & -1 \\ .2200 & -1 \\ \end{array}$	.1880 -1 .1874 -1 .1868 -1 .1862 -1 .1857 -1
6. 45	. 4045 -3	.3771 -2 $.3745 -2$ $.3719 -2$ $.3693 -2$ $.3668 -2$	. 1073	6. 372	.1178 -1	72. 65	2. 314359	87. 867	8. 919	. 4007	48. 37	5. 356	9. 031	.2186 -1	. 1851 -1
6. 46	. 4006 -3		. 1070	6. 382	.1170 -1	73. 14	2. 314743	87. 927	8. 905	. 4007	48. 52	5. 358	9. 056	.2171 -1	. 1845 -1
6. 47	. 3968 -3		. 1067	6. 392	.1163 -1	73. 63	2. 315126	87. 988	8. 891	. 4006	48. 67	5. 360	9. 081	.2157 -1	. 1840 -1
6. 48	. 3930 -3		. 1064	6. 402	.1155 -1	74. 13	2. 315507	88. 048	8. 877	. 4005	48. 82	5. 362	9. 106	.2143 -1	. 1834 -1
6. 49	. 3892 -3		. 1061	6. 412	.1148 -1	74. 63	2. 315886	88. 108	8. 864	. 4004	48. 97	5. 363	9. 131	.2129 -1	. 1828 -1
6. 50 6. 51 6. 52 6. 53 6. 54	.3855 -3 $.3818 -3$ $.3781 -3$ $.3745 -3$ $.3709 -3$	$\begin{array}{cccc} .3643 & -2 \\ .3618 & -2 \\ .3593 & -2 \\ .3568 & -2 \\ .3544 & -2 \end{array}$	. 1058 . 1055 . 1052 . 1050 . 1047	6. 423 6. 433 6. 443 6. 453 6. 463	.1140 -1 .1133 -1 .1125 -1 .1118 -1 .1111 -1	75. 13 75. 65 76. 15 76. 66 77. 18	2. 316264 2. 316640 2. 317015 2. 317388 2. 317760	88. 169 88. 228 88. 288 88. 347 88. 406	8. 850 8. 836 8. 823 8. 809 8. 795	. 4004 . 4003 . 4002 . 4002 . 4001	49. 13 49. 28 49. 43 49. 58 49. 73	5. 365 5. 367 5. 369 5. 370 5. 372	9. 156 9. 182 9. 207 9. 232 9. 258	. 2115 -1 . 2101 -1 . 2087 -1 . 2073 -1 . 2060 -1	. 1823 -1 . 1817 -1 . 1812 -1 . 1806 -1 . 1801 -1
6. 55 6. 56 6. 57 6. 58 6. 59	. 3674 -3 . 3639 -3 . 3604 -3 . 3570 -3 . 3536 -3	$\begin{array}{cccc} .3520 & -2 \\ .3496 & -2 \\ .3472 & -2 \\ .3449 & -2 \\ .3425 & -2 \end{array}$	. 1044 . 1041 . 1038 . 1035 . 1032	6. 473 6. 483 6. 493 6. 504 6. 514	$\begin{array}{cccc} .1103 & ^{-1} \\ .1096 & ^{-1} \\ .1089 & ^{-1} \\ .1082 & ^{-1} \\ .1075 & ^{-1} \\ \end{array}$	77. 69 78. 21 78. 74 79. 26 79. 79	2. 318130 2. 318499 2. 318866 2. 319232 2. 319596	88. 466 88. 525 88. 584 88. 642 88. 701	8. 782 8. 768 8. 755 8. 741 8. 728	. 4000 . 4000 . 3999 . 3999 . 3998	49. 89 50. 04 50. 19 50. 35 50. 50	5. 374 5. 375 5. 377 5. 379 5. 381	9. 283 9. 309 9. 334 9. 360 9. 386	. 2047 -1 . 2033 -1 . 2020 -1 . 2007 -1 . 1994 -1	. 1795 -1 . 1790 -1 . 1784 -1 . 1779 -1 . 1774 -1
6. 60 6. 61 6. 62 6. 63 6. 64	$\begin{array}{ccccc} .3503 & ^{-3} \\ .3470 & ^{-3} \\ .3437 & ^{-3} \\ .3404 & ^{-3} \\ .3372 & ^{-3} \end{array}$	$\begin{array}{cccc} .3402 & -2 \\ .3379 & -2 \\ .3356 & -2 \\ .3333 & -2 \\ .3311 & -2 \\ \end{array}$	. 1030 . 1027 . 1024 . 1021 . 1019	6. 524 6. 534 6. 544 6. 554 6. 564	.1068 -1 .1061 -1 .1054 -1 .1048 -1 .1041 -1	80. 32 80. 86 81. 40 81. 94 82. 48	2. 319959 2. 320320 2. 320679 2. 321038 2. 321395	88. 760 88. 818 88. 876 88. 934 88. 991	8. 715 8. 702 8. 688 8. 675 8. 662	. 3997 . 3997 . 3996 . 3995 . 3995	50. 65 50. 81 50. 96 51. 12 51. 27	5. 382 5. 384 5. 386 5. 387 5. 389	9. 411 9. 437 9. 463 9. 488 9. 514	. 1981 -1 . 1968 -1 . 1955 -1 . 1943 -1 . 1930 -1	. 1768 -1 . 1763 -1 . 1758 -1 . 1753 -1 . 1747 -1

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#### TABLE II.—SUPERSONIC FLOW—Continued

$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho \iota}$	$rac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
6. 65 6. 66 6. 67 6. 68 6. 69	$\begin{array}{c} .3341 & ^{-3} \\ .3309 & ^{-3} \\ .3278 & ^{-3} \\ .3247 & ^{-3} \\ .3217 & ^{-3} \end{array}$	$\begin{array}{cccc} .3289 & -2 \\ .3267 & -2 \\ .3245 & -2 \\ .3223 & -2 \\ .3201 & -2 \end{array}$	. 1016 . 1013 . 1010 . 1008 . 1005	6. 574 6. 584 6. 595 6. 605 6. 615	. 1034 -1 . 1028 -1 . 1021 -1 . 1014 -1 . 1008 -1	83. 03 83. 58 84. 13 84. 68 85. 24	2. 321750 2. 322104 2. 322456 2. 322807 2. 323157	89, 049 89, 106 89, 164 89, 221 89, 278	8. 649 8. 636 8. 623 8. 610 8. 597	. 3994 . 3993 . 3993 . 3992 . 3992	51. 43 51. 58 51. 74 51. 89 52. 05	5. 391 5. 392 5. 394 5. 395 5. 397	9. 540 9. 566 9. 592 9. 618 9. 644	. 1918 -1 . 1905 -1 . 1893 -1 . 1881 -1 . 1869 -1	. 1742 -1 . 1737 -1 . 1732 -1 . 1727 -1 . 1721 -1
6. 70 6. 71 6. 72 6. 73 6. 74	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{ccccc} .3180 & ^{-2}\\ .3158 & ^{-2}\\ .3137 & ^{-2}\\ .3116 & ^{-2}\\ .3096 & ^{-2}\\ \end{array}$	. 1002 . 9995 -1 . 9968 -1 . 9942 -1 . 9915 -1	6. 625 6. 635 6. 645 6. 655 6. 665	. 1001 -1 . 9950 -2 . 9886 -2 . 9823 -2 . 9761 -2	85. 80 86. 37 86. 94 87. 51 88. 08	2. 323505 2. 323852 2. 324198 2. 324542 2. 324884	89. 335 89. 391 89. 448 89. 504 89. 561	8. 584 8. 571 8. 558 8. 545 8. 532	. 3991 . 3990 . 3990 . 3989 . 3988	52. 21 52. 36 52. 52 52. 68 52. 83	5. 399 5. 400 5. 402 5. 403 5. 405	9. 670 9. 696 9. 722 9. 748 9: 775	. 1857 -1 . 1845 -1 . 1833 -1 . 1821 -1 . 1810 -1	.1716 -1 .1711 -1 .1706 -1 .1701 -1 .1696 -1
6. 75 6. 76 6. 77 6. 78 6. 79	. 3041 -3 . 3013 -3 . 2985 -3 . 2957 -3 . 2930 -3	$\begin{array}{ccccc} .3075 & -2 \\ .3055 & -2 \\ .3034 & -2 \\ .3014 & -2 \\ .2994 & -2 \\ \end{array}$	$\begin{array}{ccccc} .9889 & ^{-1} \\ .9862 & ^{-1} \\ .9836 & ^{-1} \\ .9810 & ^{-1} \\ .9784 & ^{-1} \end{array}$	6. 676 6. 686 6. 696 6. 706 6. 716	$\begin{array}{ccccc} .9699 & -2 \\ .9637 & -2 \\ .9576 & -2 \\ .9515 & -2 \\ .9454 & -2 \\ \end{array}$	88. 66 89. 24 89. 82 90. 41 91. 00	2. 325226 2. 325566 2. 325904 2. 326242 2. 326578	89. 617 89. 673 89. 729 89. 784 89. 840	8. 520 8. 507 8. 494 8. 482 8. 469	. 3988 . 3987 . 3987 . 3986 . 3986	52, 99 53, 15 53, 31 53, 46 53, 62	5. 407 5. 408 5. 410 5. 411 5. 413	9. 801 9. 827 9. 853 9. 880 9. 906	. 1798 -1 . 1786 -1 . 1775 -1 . 1764 -1 . 1753 -1	.1691 -1 .1686 -1 .1681 -1 .1677 -1 .1671 -1
6. 80 6. 81 6. 82 6. 83 6. 84	. 2902 -3 . 2876 -3 . 2849 -3 . 2823 -3 . 2797 -3	$\begin{array}{cccc} .2974 & -2 \\ .2955 & -2 \\ .2935 & -2 \\ .2916 & -2 \\ .2897 & -2 \\ \end{array}$	. 9758 -1 . 9732 -1 . 9706 -1 . 9681 -1 . 9655 -1	6. 726 6. 736 6. 746 6. 756 6. 767	$\begin{array}{ccccc} .9395 & -2 \\ .9335 & -2 \\ .9276 & -2 \\ .9218 & -2 \\ .9160 & -2 \\ \end{array}$	91. 59 92. 19 92. 79 93. 39 94. 00	2. 326912 2. 327245 2. 327577 2. 327908 2. 328237	89. 895 89. 950 90. 005 90. 060 90. 116	8. 457 8. 444 8. 432 8. 419 8. 407	. 3985 . 3984 . 3984 . 3983 . 3983	53. 78 53. 94 54. 10 54. 26 54. 42	5. 415 5. 416 5. 418 5. 419 5. 421	9, 933 9, 959 9, 986 10, 01 10, 04	. 1741 -1 . 1730 -1 . 1719 -1 . 1709 -1 . 1698 -1	. 1667 -1 . 1662 -1 . 1657 -1 . 1652 -1 . 1647 -1
6, 85 6, 86 6, 87 6, 88 6, 89	$\begin{array}{c ccccc} .2771 & -3 \\ .2746 & -3 \\ .2720 & -3 \\ .2696 & -3 \\ .2671 & -3 \\ \end{array}$	$\begin{array}{cccc} .2878 & -2 \\ .2859 & -2 \\ .2840 & -2 \\ .2821 & -2 \\ .2803 & -2 \\ \end{array}$	. 9630 -1 . 9604 -1 . 9579 -1 . 9554 -1 . 9529 -1	6, 777 6, 787 6, 797 6, 807 6, 817	. 9102 -2 . 9045 -2 . 8988 -2 . 8931 -2 . 8875 -2	94. 61 95. 22 95. 83 96. 45 97. 08	2. 328565 2. 328892 2. 329217 2. 329541 2. 329864	90. 170 90. 225 90. 279 90. 333 90. 387	8, 394 8, 382 8, 370 8, 357 8, 345	.3982 .3981 .3981 .3980 .3980	54. 58 54. 74 54. 90 55. 06 55. 22	5, 422 5, 424 5, 425 5, 427 5, 428	10. 07 10. 09 10. 12 10. 15 10. 17	. 1687 -1 . 1676 -1 . 1666 -1 . 1655 -1 . 1645 -1	. 1643 -1 . 1638 -1 . 1633 -1 . 1628 -1 . 1624 -1
6, 90 6, 91 6, 92 6, 93 6, 94	$\begin{array}{c} .2646 & ^{-3}\\ .2622 & ^{-3}\\ .2598 & ^{-3}\\ .2575 & ^{-3}\\ .2551 & ^{-3} \end{array}$	. 2785 -2 . 2766 -2 . 2748 -2 . 2730 -2 . 2713 -2	. 9504 -i . 9479 -i . 9454 -i . 9430 -i . 9405 -i	6. 827 6. 837 6. 847 6. 857 6. 868	. 8820 -2 . 8764 -2 . 8710 -2 . 8655 -2 . 8601 -2	97. 70 98. 33 98. 96 99. 60 100. 2	2. 330186 2. 330506 2. 330825 2. 331143 2. 331460	90. 441 90. 495 90. 549 90. 602 90. 655	8, 333 8, 321 8, 309 8, 297 8, 285	.3979 .3979 .3978 .3977 .3977	55. 38 55. 54 55. 70 55. 86 56. 02	5. 430 5. 431 5. 433 5. 434 5. 436	10. 20 10. 23 10. 25 10. 28 10. 31	. 1634 -1 . 1624 -1 . 1614 -1 . 1604 -1 . 1594 -1	$\begin{array}{ccccc} .\ 1619 & ^{-1}\\ .\ 1614 & ^{-i}\\ .\ 1610 & ^{-1}\\ .\ 1605 & ^{-1}\\ .\ 1601 & ^{-1}\\ \end{array}$
6, 95 6, 96 6, 97 6, 98 6, 99	. 2528 -3 . 2505 -3 . 2482 -3 . 2460 -3 . 2438 -3	. 2695 -2 . 2677 -2 . 2660 -2 . 2643 -2 . 2626 -2	. 9380 -1 . 9356 -1 . 9332 -1 . 9307 -1 . 9283 -1	6, 878 6, 888 6, 898 6, 908 6, 918	. 8548 -2 . 8495 -2 . 8442 -2 . 8389 -2 . 8337 -2	100. 9 101. 5 102. 2 102. 8 103. 5	2. 331775 2. 332089 2. 332402 2. 332714 2. 333024	90, 709 90, 762 90, 815 90, 867 90, 920	8. 273 8. 261 8. 249 8. 237 8. 225	.3976 .3976 .3975 .3975 .3974	56, 19 56, 35 56, 51 56, 67 56, 84	5. 437 5. 439 5. 440 5. 442 5. 443	10. 33 10. 36 10. 39 10. 42 10. 44	.1584 -1 .1574 -1 .1564 -! .1554 -1 .1545 -1	.1596 -1 .1592 -1 .1587 -1 .1582 -1 .1578 -1
7. 00 7. 01 7. 02 7. 03 7. 04	$\begin{array}{c} .2416 & ^{-3} \\ .2394 & ^{-3} \\ .2372 & ^{-3} \\ .2351 & ^{-3} \\ .2330 & ^{-3} \end{array}$	$\begin{array}{cccc} .2609 & -2 \\ .2592 & -2 \\ .2575 & -2 \\ .2559 & -2 \\ .2542 & -2 \\ \end{array}$	$\begin{array}{c} .9259 & -1 \\ .9235 & -1 \\ .9211 & -1 \\ .9188 & -1 \\ .9164 & -1 \\ \end{array}$	6. 928 6. 938 6. 948 6. 959 6. 969	$\begin{array}{ccccc} .8286 & ^{-2} \\ .8234 & ^{-2} \\ .8183 & ^{-2} \\ .8133 & ^{-2} \\ .8082 & ^{-2} \end{array}$	104. 1 104. 8 105. 5 106. 1 106. 8	2. 333333 2. 333641 2. 333948 2. 334254 2. 334558	90, 973 91, 026 91, 078 91, 130 91, 182	8. 213 8. 201 8. 190 8. 178 8. 166	.3974 .3973 .3973 .3972 .3971	57. 00 57. 16 57. 33 57. 49 57. 66	5. 444 5. 446 5. 447 5. 449 5. 450	10. 47 10. 50 10. 52 10. 55 10. 58	. 1535 -1 . 1526 -1 . 1516 -1 . 1507 -1 . 1497 -1	. 1574 -1 . 1569 -1 . 1565 -1 . 1560 -1 . 1556 -1
7. 05 7. 06 7. 07 7. 08 7. 09	. 2309 -3 . 2288 -3 . 2267 -3 . 2247 -3 . 2227 -3	. 2526 -2 . 2510 -2 . 2494 -2 . 2478 -2 . 2462 -2	. 9140 -1 . 9117 -1 . 9093 -1 . 9070 -1 . 9047 -1	6. 979 6. 989 6. 999 7. 009 7. 019	.8032 -2 .7983 -2 .7934 -2 .7885 -2 .7837 -2	107. 5 108. 2 108. 9 109. 5 110. 2	2. 334862 2. 335164 2. 335465 2. 335765 2. 336063	91, 234 91, 286 91, 337 91, 389 91, 440	8. 155 8. 143 8. 131 8. 120 8. 108	.3971 .3970 .3970 .3969 .3969	57. 82 57. 98 58. 15 58. 31 58. 48	5, 452 5, 453 5, 454 5, 456 5, 457	10. 61 10. 63 10. 66 10. 69 10. 72	$\begin{array}{ccccc} .1488 & -1 \\ .1479 & -1 \\ .1470 & -1 \\ .1461 & -1 \\ .1452 & -1 \\ \end{array}$	. 1551 -1 . 1547 -1 . 1543 -1 . 1538 -1 . 1534 -1
7. 10 7. 11 7. 12 7. 13 7. 14	. 2207 -3 . 2187 -3 . 2168 -3 . 2149 -3 . 2130 -3	$\begin{array}{cccc} .2446 & -2 \\ .2430 & -2 \\ .2415 & -2 \\ .2400 & -2 \\ .2384 & -2 \\ \end{array}$	. 9024 -1 . 9001 -1 . 8978 -1 . 8955 -1 . 8932 -1	7. 029 7. 039 7. 049 7. 060 7. 070	$\begin{array}{cccc} .7789 & ^{-2} \\ .7741 & ^{-2} \\ .7693 & ^{-2} \\ .7646 & ^{-2} \\ .7600 & ^{-2} \end{array}$	110. 9 111. 6 112. 3 113. 0 113. 7	2. 336361 2. 336657 2. 336952 2. 337246 2. 337539	91. 492 91. 543 91. 594 91. 645 91. 695	8. 097 8. 085 8. 074 8. 062 8. 051	.3968 .3968 .3967 .3967 .3966	58, 65 58, 81 58, 98 59, 14 59, 31	5. 459 5. 460 5. 461 5. 463 5. 464	10. 74 10. 77 10. 80 10. 83 10. 85	.1443 -I .1434 -I .1425 -I .1416 -I .1408 -I	. 1530 -1 . 1525 -1 . 1521 -1 . 1517 -1 . 1513 -1
7. 15 7. 16 7. 17 7. 18 7. 19	. 2111 -3 . 2092 -3 . 2073 -3 . 2055 -3 . 2037 -3	$\begin{array}{cccc} .2369 & -2 \\ .2354 & -2 \\ .2339 & -2 \\ .2324 & -2 \\ .2310 & -2 \\ \end{array}$	. 8909 -1 . 8886 -i . 8864 -1 . 8841 -1 . 8819 -1	7. 080 7. 090 7. 100 7. 110 7. 120	$\begin{array}{cccc} .7553 & -2 \\ .7507 & -2 \\ .7461 & +2 \\ .7416 & -2 \\ .7371 & -2 \\ \end{array}$	114. 5 115. 2 115. 9 116. 6 117. 3	2. 337831 2. 338122 2. 338412 2. 338700 2. 338988	91, 746 91, 796 91, 847 91, 897 91, 947	8, 040 8, 028 8, 017 8, 006 7, 995	.3966 .3965 .3965 .3964 .3964	59. 48 59. 64 59. 81 59. 98 60. 15	5, 465 5, 467 5, 468 5, 470 5, 471	10. 88 10. 91 10. 94 10. 97 10. 99	.1399 -1 .1390 -1 .1382 -1 .1374 -1 .1365 -1	.1509 -1 .1504 -1 .1500 -1 .1496 -1 .1492 -1
7. 20 7. 21 7. 22 7. 23 7. 24	$\begin{array}{c ccccc} .2019 & ^{-3} \\ .2001 & ^{-3} \\ .1983 & ^{-3} \\ .1966 & ^{-3} \\ .1949 & ^{-3} \\ \end{array}$	$\begin{array}{cccc} .2295 & -2 \\ .2281 & -2 \\ .2266 & -2 \\ .2252 & -2 \\ .2238 & -2 \\ \end{array}$	. 8797 -1 . 8774 -1 . 8752 -1 . 8730 -1 . 8708 -1	7. 130 7. 140 7. 150 7. 161 7. 171	$\begin{array}{cccc} .7326 & -2 \\ .7281 & -2 \\ .7237 & -2 \\ .7194 & -2 \\ .7150 & -2 \\ \end{array}$	118. 1 118. 8 119. 6 120. 3 121. 0	2. 339274 2. 339559 2. 339843 2. 340127 2. 340409	91, 997 92, 047 92, 097 92, 146 92, 196	7. 984 7. 972 7. 961 7. 950 7. 939	. 3963 . 3963 . 3962 . 3962 . 3961	60. 31 60. 48 60. 65 60. 82 60. 99	5. 472 5. 474 5. 475 5. 476 5. 478	11. 02 11. 05 11. 08 11. 11 11. 13	. 1357 -1 . 1349 -1 . 1340 -1 . 1332 -1 . 1324 -1	.1488 -1 .1484 -1 .1480 -1 .1476 -1 .1472 -1
7. 25 7. 26 7. 27 7. 28 7. 29	. 1932 -3 . 1915 -3 . 1898 -3 . 1881 -3 . 1865 -3	$\begin{array}{cccc} .2224 & -2 \\ .2210 & -2 \\ .2196 & -2 \\ .2182 & -2 \\ .2169 & -2 \\ \end{array}$	.8686 -1 .8664 -1 .8643 -1 .8621 -1 .8599 -1	7. 181 7. 191 7. 201 7. 211 7. 221	.7107 -2 .7064 -2 .7021 -2 .6979 -2 .6937 -2	121. 8 122. 5 123. 3 124. 1 124. 8	2. 340690 2. 340969 2. 341248 2. 341526 2. 341803	92, 245 92, 294 92, 343 92, 392 92, 441	7. 928 7. 917 7. 906 7. 895 7. 884	.3961 .3960 .3960 .3959 .3959	61. 16 61. 33 61. 50 61. 66 61. 83	5. 479 5. 480 5. 481 5. 483 5. 484	11. 16 11. 19 11. 22 11. 25 11. 28	. 1316 -1 . 1308 -1 . 1300 -1 . 1292 -1 . 1285 -1	.1468 -1 .1464 -1 .1460 -1 .1456 -1 .1452 -1
7.30 7.31 7.32 7.33 7.34	. 1848 -3 . 1832 -3 . 1816 -3 . 1801 -3 . 1785 -3	$\begin{array}{cccc} .2155 & -2 \\ .2142 & -2 \\ .2128 & -2 \\ .2115 & -2 \\ .2102 & -2 \\ \end{array}$	.8578 -1 .8556 -1 .8535 -1 .8514 -1 .8492 -1	7. 231 7. 241 7. 251 7. 261 7. 272	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	125. 6 126. 4 127. 2 127. 9 128. 7	2. 342079 2. 342353 2. 342627 2. 342900 2. 343171	92. 490 92. 538 92. 587 92. 635 92. 684	7.874 7.863 7.852 7.841 7.830	. 3958 . 3958 . 3957 . 3957 . 3956	62. 01 62. 18 62. 35 62. 52 62. 69	5. 485 5. 487 5. 488 5. 489 5. 490	11. 30 11. 33 11. 36 11. 39 11. 42	. 1277 -1 . 1269 -1 . 1262 -1 . 1254 -1 . 1246 -1	.1448 -  .1444 -  .1440 -  .1436 -  .1432 -
7. 35 7. 36 7. 37 7. 38 7. 39	$\begin{array}{cccc} .1769 & ^{-3} \\ .1754 & ^{-3} \\ .1739 & ^{-3} \\ .1724 & ^{-3} \\ .1709 & ^{-3} \end{array}$	$\begin{array}{cccc} .2089 & ^{-2} \\ .2076 & ^{-2} \\ .2063 & ^{-2} \\ .2050 & ^{-2} \\ .2037 & ^{-2} \\ \end{array}$	.8471 -1 .8450 -1 .8429 -1 .8408 -1 .8388 -1	7. 282 7. 292 7. 302 7. 312 7. 322	$\begin{array}{ccccc} .6691 & -2 \\ .6651 & -2 \\ .6612 & -2 \\ .6572 & -2 \\ .6533 & -2 \\ \end{array}$	129. 5 130. 3 131. 1 131. 9 132. 7	2. 343442 2. 343711 2. 343980 2. 344248 2. 344514	92, 732 92, 780 92, 828 92, 876 92, 923	7. 820 7. 809 7. 798 7. 788 7. 777	. 3956 . 3955 . 3955 . 3955 . 3954	62. 86 63. 03 63. 20 63. 38 63. 55	5. 492 5. 493 5. 494 5. 495 5. 497	11. 45 11. 48 11. 50 11. 53 11. 56	. 1239 -1 . 1232 -1 . 1224 -1 . 1217 -1 . 1210 -1	.1428 -1 .1424 -1 .1421 -1 .1417 -1 .1413 -1
7. 40 7. 41 7. 42 7. 43 7. 44	$\begin{array}{ccccc} .1694 & -3 \\ .1680 & -3 \\ .1665 & -3 \\ .1651 & -3 \\ .1637 & -3 \\ \end{array}$	$\begin{array}{cccc} .2025 & -2 \\ .2012 & -2 \\ .2000 & -2 \\ .1988 & -2 \\ .1975 & -2 \\ \end{array}$	.8367 -1 .8346 -1 .8326 -1 .8305 -1 .8285 -1	7, 332 7, 342 7, 352 7, 362 7, 372	$\begin{array}{ccccc} .6494 & -2 \\ .6456 & -2 \\ .6417 & -2 \\ .6379 & -2 \\ .6341 & -2 \\ \end{array}$	133. 5 134. 3 135. 2 136. 0 136. 8	2. 344780 2. 345044 2. 345308 2. 345571 2. 345832	92, 971 93, 018 93, 066 93, 112 93, 160	7. 766 7. 756 7. 745 7. 735 7. 724	. 3954 . 3953 . 3953 . 3952 . 3952	63. 72 63. 89 64. 07 64. 24 64. 41	5, 498 5, 499 5, 500 5, 502 5, 503	11. 59 11. 62 11. 65 11. 68 11. 71	. 1202 -1 . 1195 -1 . 1188 -1 . 1181 -1 . 1174 -1	.1409 -1 .1405 -1 .1402 -1 .1398 -1 .1394 -1
7. 45 7. 46 7. 47 7. 48 7. 49	$\begin{array}{cccc} .1623 & ^{-3} \\ .1609 & ^{-3} \\ .1595 & ^{-3} \\ .1581 & ^{-3} \\ .1568 & ^{-3} \\ \end{array}$	$\begin{array}{cccc} .1963 & -2 \\ .1951 & -2 \\ .1939 & -2 \\ .1927 & -2 \\ .1916 & -2 \\ \end{array}$	.8264 -1 .8244 -1 .8224 -1 .8203 -1 .8183 -1	7. 383 7. 393 7. 403 7. 413 7. 423	.6304 -2 .6267 -2 .6229 -2 .6193 -2 .6156 -2	137. 6 138. 5 139. 3 140. 1 141. 0	2. 346093 2. 346353 2. 346612 2. 346870 2. 347126	93. 207 93. 254 93. 300 93. 347 93. 394	7. 714 7. 704 7. 693 7. 683 7. 673	. 3951 . 3951 . 3950 . 3950 . 3950	64. 59 64. 76 64. 93 65. 11 65. 28	5. 504 5. 505 5. 507 5. 508 5. 509	11. 73 11. 76 11. 79 11. 82 11. 85	. 1167 -1 . 1160 -1 . 1153 -1 . 1146 -1 . 1140 -1	. 1390 -1 . 1387 -1 . 1383 -1 . 1379 -1 . 1376 -1
7. 50 7. 51 7. 52 7. 53 7. 54	$\begin{array}{c} .1554 & -3 \\ .1541 & -3 \\ .1528 & -3 \\ .1515 & -3 \\ .1502 & -3 \\ \end{array}$	. 1904 -2 . 1892 -2 . 1881 -2 . 1869 -2 . 1858 -2	.8163 -1 .8143 -1 .8123 -1 .8104 -1 .8084 -1	7. 433 7. 443 7. 453 7. 463 7. 473	.6120 -2 .6084 -2 .6048 -2 .6013 -2 .5977 -2	141. 8 142. 7 143. 6 144. 4 145. 3	2. 347382 2. 347637 2. 347892 2. 348145 2. 348397	93. 440 93. 487 93. 533 93. 579 93. 624	7. 662 7. 652 7. 642 7. 632 7. 621	. 3949 . 3949 . 3948 . 3948 . 3947	65. 46 65. 63 65. 81 65. 98 66. 16	5. 510 5. 511 5. 513 5. 514 5. 515	11, 88 11, 91 11, 94 11, 97 12, 00	.1133 -1 .1126 -1 .1120 -1 .1113 -1 .1106 -1	. 1372 -1 . 1368 -1 . 1365 -1 . 1361 -1 . 1358 -1

#### EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

#### TABLE II.—SUPERSONIC FLOW—Continued

$\gamma = 7/5$															
$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho_i}$	$rac{T}{T_t}$	β	$\frac{q}{p_i}$	$rac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\left.rac{p_1}{p_{t_2}} ight.$
7. 55	. 1489 -3	$\begin{array}{cccc} .1847 & -2 \\ .1836 & -2 \\ .1824 & -2 \\ .1813 & -2 \\ .1802 & -2 \\ \end{array}$	. 8064 -1	7. 483	. 5942 -2	146. 2	2. 348648	93. 670	7. 611	. 3947	66. 34	5. 516	12.03	. 1100 -1	. 1354 -1
7. 56	. 1477 -3		. 8045 -1	7. 494	. 5908 -2	147. 0	2. 348899	93. 716	7. 601	. 3946	66. 51	5. 517	12.06	. 1093 -1	. 1351 -1
7. 57	. 1464 -3		. 8025 -1	7. 504	. 5873 -2	147. 9	2. 349148	93. 762	7. 591	. 3946	66. 69	5. 518	12.09	. 1087 -1	. 1347 -1
7. 58	. 1452 -3		. 8006 -1	7. 514	. 5839 -2	148. 8	2. 349397	93. 807	7. 581	. 3946	66. 87	5. 520	12.11	. 1081 -1	. 1343 -1
7. 59	. 1439 -3		. 7986 -1	7. 524	. 5805 -2	149. 7	2. 349644	93. 853	7. 571	. 3945	67. 04	5. 521	12.14	. 1074 -1	. 1340 -1
7. 60	.1427 -3	. 1792 -2	. 7967 -1	7. 534	. 5771 -2	150, 6	2. 349891	93. 898	7. 561	. 3945	67. 22	5. 522	12. 17	. 1068 -1	. 1336 -1
7. 61	.1415 -3	. 1781 -2	. 7948 -1	7. 544	. 5737 -2	151, 5	2. 350137	93. 943	7. 551	. 3944	67. 40	5. 523	12. 20	. 1062 -1	. 1333 -1
7. 62	.1403 -3	. 1770 -2	. 7928 -1	7. 554	. 5704 -2	152, 4	2. 350382	93. 988	7. 541	. 3944	67. 58	5. 524	12. 23	. 1056 -1	. 1329 -1
7. 63	.1391 -3	. 1759 -2	. 7909 -1	7. 564	. 5671 -2	153, 3	2. 350626	94. 033	7. 531	. 3943	67. 75	5. 525	12. 26	. 1049 -1	. 1326 -1
7. 64	.1380 -3	. 1749 -2	. 7890 -1	7. 574	. 5638 -2	154, 2	2. 350869	94. 078	7. 521	. 3943	67. 93	5. 527	12. 29	. 1043 -1	. 1322 -1
7. 65	.1368 -3	$\begin{array}{cccc} .1738 & ^{-2}\\ .1728 & ^{-2}\\ .1717 & ^{-2}\\ .1707 & ^{-2}\\ .1697 & ^{-2}\\ \end{array}$	.7871 -1	7. 584	.5605 -2	155. 1	2. 351112	94. 123	7. 511	. 3943	68. 11	5. 528	12. 32	. 1037 -1	. 1319 -1
7. 66	.1357 -3		.7852 -1	7. 594	.5572 -2	156. 0	2. 351353	94. 168	7. 501	. 3942	68. 29	5. 529	12. 35	. 1031 -1	. 1316 -1
7. 67	.1345 -3		.7833 -1	7. 605	.5540 -2	157. 0	2. 351594	94. 212	7. 491	. 3942	68. 47	5. 530	12. 38	. 1025 -1	. 1312 -1
7. 68	.1334 -3		.7815 -1	7. 615	.5508 -2	157. 9	2. 351834	94. 257	7. 482	. 3941	68. 65	5. 531	12. 41	. 1019 -1	. 1309 -1
7. 69	.1323 -3		.7796 -1	7. 625	.5476 -2	158. 8	2. 352072	94. 301	7. 472	. 3941	68. 83	5. 532	12. 44	. 1013 -1	. 1305 -1
7. 70	. 1312 -3	.1687 -2	.7777 -1	7. 635	.5445 -2	159. 8	2, 352310	94. 345	7. 462	. 3941	69. 01	5. 533	12. 47	. 1008 -1	.1302 -1
7. 71	. 1301 -3	.1677 -2	.7759 -1	7. 645	.5413 -2	160. 7	2, 352548	94. 389	7. 452	. 3940	69. 18	5. 534	12. 50	. 1002 -1	.1299 -1
7. 72	. 1290 -3	.1667 -2	.7740 -1	7. 655	.5382 -2	161. 7	2, 352784	94. 433	7. 443	. 3940	69. 36	5. 536	12. 53	. 9959 -2	.1295 -1
7. 73	. 1279 -3	.1657 -2	.7722 -1	7. 665	.5351 -2	162. 6	2, 353019	94. 477	7. 433	. 3939	69. 55	5. 537	12. 56	. 9902 -2	.1292 -1
7. 74	. 1269 -3	.1647 -2	.7703 -1	7. 675	.5320 -2	163. 6	2, 353254	94. 521	7. 423	. 3939	69. 73	5. 538	12. 59	. 9845 -2	.1289 -1
7. 75	.1258 -3	.1637 -2	.7685 -1	7. 685	. 5290 -2	164. 5	2. 353488	94. 565	7. 414	. 3939	69. 91	5. 539	12. 62	. 9788 -2	.1285 -1
7. 76	.1248 -3	.1627 -2	.7667 -1	7. 695	. 5259 -2	165. 5	2. 353721	94. 608	7. 404	. 3938	70. 09	5. 540	12. 65	. 9732 -2	.1282 -1
7. 77	.1237 -3	.1618 -2	.7648 -1	7. 705	. 5229 -2	166. 5	2. 353953	94. 652	7. 395	. 3938	70. 27	5. 541	12. 68	. 9676 -2	.1279 -1
7. 78	.1227 -3	.1608 -2	.7630 -1	7. 715	. 5199 -2	167. 4	2. 354184	94. 695	7. 385	. 3937	70. 45	5. 542	12. 71	. 9620 -2	.1276 -1
7. 79	.1217 -3	.1599 -2	.7612 -1	7. 726	. 5170 -2	168. 4	2. 354415	94. 739	7. 375	. 3937	70. 63	5. 543	12. 74	. 9565 -2	.1272 -1
7. 80	.1207 -3	.1589 -2	.7594 -1	7. 736	.5140 -2	169. 4	2. 354644	94. 782	7. 366	. 3937	70. 81	5. 544	12.77	. 9510 -2	.1269 -1
7. 81	.1197 -3	.1580 -2	.7576 -1	7. 746	.5111 -2	170. 4	2. 354873	94. 825	7. 356	. 3936	71. 00	5. 545	12.80	. 9456 -2	.1266 -1
7. 82	.1187 -3	.1571 -2	.7558 -1	7. 756	.5082 -2	171. 4	2. 355101	94. 868	7. 347	. 3936	71. 18	5. 547	12.83	. 9402 -2	.1263 -1
7. 83	.1177 -3	.1561 -2	.7540 -1	7. 766	.5053 -2	172. 4	2. 355328	94. 911	7. 338	. 3935	71. 36	5. 548	12.86	. 9348 -2	.1259 -1
7. 84	.1168 -3	.1552 -2	.7523 -1	7. 776	.5024 -2	173. 4	2. 355555	94. 954	7. 328	. 3935	71. 54	5. 549	12.89	. 9295 -2	.1256 -1
7. 85	. 1158 -3	.1543 -2	.7505 -1	7. 786	. 4995 -2	174. 4	2. 355780	94. 996	7. 319	. 3935	71. 73	5. 550	12. 92	. 9242 -2	.1253 -1
7. 86	. 1149 -3	.1534 -2	.7487 -1	7. 796	. 4967 -2	175. 4	2. 356005	95. 039	7. 309	. 3934	71. 91	5. 551	12. 96	. 9189 -2	.1250 -1
7. 87	. 1139 -3	.1525 -2	.7470 -1	7. 806	. 4939 -2	176. 4	2. 356229	95. 082	7. 300	. 3934	72. 09	5. 552	12. 99	. 9137 -2	.1247 -1
7. 88	. 1130 -3	.1516 -2	.7452 -1	7. 816	. 4911 -2	177. 5	2. 356453	95. 124	7. 291	. 3933	72. 28	5. 553	13. 02	. 9085 -2	.1244 -1
7. 89	. 1121 -3	.1507 -2	.7435 -1	7. 826	. 4883 -2	178. 5	2. 356675	95. 166	7. 281	. 3933	72. 46	5. 554	13. 05	. 9033 -2	.1241 -1
7. 90	.1111 -3	. 1498 -2	.7417 -1	7, 836	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	179. 5	2. 356897	95. 208	7. 272	. 3933	72. 65	5. 555	13. 08	. 8982 -2	.1237 -1
7. 91	.1102 -3	. 1490 -2	.7400 -1	7, 847		180. 5	2. 357118	95. 251	7. 263	. 3932	72. 83	5. 556	13. 11	. 8931 -2	.1234 -1
7. 92	.1093 -3	. 1481 -2	.7383 -1	7, 857		181. 6	2. 357338	95. 293	7. 254	. 3932	73. 01	5. 557	13. 14	. 8880 -2	.1231 -1
7. 93	.1084 -3	. 1472 -2	.7365 -1	7, 867		182. 6	2. 357557	95. 334	7. 245	. 3932	73. 20	5. 558	13. 17	. 8830 -2	.1228 -1
7. 94	.1076 -3	. 1464 -2	.7348 -1	7, 877		183. 7	2. 357776	95. 376	7. 235	. 3931	73. 38	5. 559	13. 20	. 8780 -2	.1225 -1
7. 95	. 1067 -3	. 1455 -2	.7331 -1	7. 887	. 4720 -2	184. 7	2. 357994	95. 418	7. 226	. 3931	73. 57	5. 560	13. 23	.8731 -2	.1222 -1
7. 96	. 1058 -3	. 1447 -2	.7314 -1	7. 897	. 4693 -2	185. 8	2. 358211	95. 460	7. 217	. 3930	73. 76	5. 561	13. 26	.8682 -2	.1219 -1
7. 97	. 1050 -3	. 1438 -2	.7297 -1	7. 907	. 4667 -2	186. 9	2. 358427	95. 501	7. 208	. 3930	73. 94	5. 562	13. 29	.8633 -2	.1216 -1
7. 98	. 1041 -3	. 1430 -2	.7280 -1	7. 917	. 4641 -2	188. 0	2. 358642	95. 542	7. 199	. 3930	74. 13	5. 563	13. 33	.8584 -2	.1213 -1
7. 99	. 1033 -3	. 1422 -2	.7263 -1	7. 927	. 4615 -2	189. 0	2. 358857	95. 584	7. 190	. 3929	74. 31	5. 564	13. 36	.8536 -2	.1210 -1
8. 00	.1024 -3	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	.7246 -1	7. 937	. 4589 -2	190. 1	2. 359071	95. 625	7. 181	. 3929	74. 50	5. 565	13. 39	.8488 -2	. 1207 -1
8. 01	.1016 -3		.7230 -1	7. 947	. 4563 -2	191. 2	2. 359285	95. 666	7. 172	. 3929	74. 69	5. 566	13. 42	.8440 -2	. 1204 -1
8. 02	.1008 -3		.7213 -1	7. 957	. 4538 -2	192. 3	2. 359497	95. 707	7. 163	. 3928	74. 87	5. 567	13. 45	.8393 -2	. 1201 -1
8. 03	.9997 -4		.7196 -1	7. 967	. 4512 -2	193. 4	2. 359709	95. 748	7. 154	. 3928	75. 06	5. 568	13. 48	.8346 -2	. 1198 -1
8. 04	.9916 -4		.7180 -1	7. 978	. 4487 -2	194. 5	2. 359920	95. 789	7. 145	. 3927	75. 25	5. 569	13. 51	.8299 -2	. 1195 -1
8. 05	. 9837 -4	$\begin{array}{cccc} .1373 & -2 \\ .1365 & -2 \\ .1358 & -2 \\ .1350 & -2 \\ .1342 & -2 \\ \end{array}$	. 7163 -1	7. 988	. 4462 -2	195. 6	2. 360130	95. 830	7. 136	. 3927	75. 44	5. 570	13. 54	. 8253 -2	.1192 -1
8. 03	. 9758 -4		. 7147 -1	7. 998	. 4437 -2	196. 7	2. 360340	95. 871	7. 127	. 3927	75. 62	5. 571	13. 57	. 8207 -2	.1189 -1
8. 07	. 9679 -4		. 7130 -1	8. 008	. 4413 -2	197. 8	2. 360549	95. 911	7. 118	. 3926	75. 81	5. 572	13. 61	. 8161 -2	.1186 -1
8. 08	. 9602 -4		. 7114 -1	8. 018	. 4388 -2	199. 0	2. 360757	95. 951	7. 109	. 3926	76. 00	5. 573	13. 64	. 8115 -2	.1183 -1
8. 09	. 9525 -4		. 7097 -1	8. 028	. 4364 -2	200. 1	2. 360965	95. 992	7. 100	. 3926	76. 19	5. 574	13. 67	. 8070 -2	.1180 -1
8. 10	. 9449 -4	.1334 -2	. 7081 -1	8. 038	. 4339 -2	201. 2	2. 361172	96. 032	7. 092	. 3925	76. 38	5. 575	13. 70	. 8025 -2	.1177 -1
8. 11	. 9373 -4	.1327 -2	. 7065 -1	8. 048	. 4315 -2	202. 4	2. 361378	96. 073	7. 083	. 3925	76. 57	5. 576	13. 73	. 7981 -2	.1174 -1
8. 12	. 9298 -4	.1319 -2	. 7049 -1	8. 058	. 4292 -2	203. 5	2. 361583	96. 112	7. 074	. 3925	76. 76	5. 577	13. 76	. 7937 -2	.1172 -1
8. 13	. 9224 -4	.1312 -2	. 7033 -1	8. 068	. 4268 -2	204. 6	2. 361788	96. 153	7. 065	. 3924	76. 95	5. 578	13. 80	. 7893 -2	.1169 -1
8. 14	. 9150 -4	.1304 -2	. 7017 -1	8. 078	. 4244 -2	205. 8	2. 361992	96. 193	7. 057	. 3924	77. 14	5. 579	13. 83	. 7849 -2	.1166 -1
8. 15 8. 16 8. 17 8. 18 8. 19	. 9078 -4 . 9005 -4 . 8934 -4 . 8863 -4 . 8793 -4	$\begin{array}{cccc} .1297 & -2 \\ .1289 & -2 \\ .1282 & -2 \\ .1275 & -2 \\ .1267 & -2 \\ \end{array}$	. 7001 -1 . 6985 -1 . 6969 -1 . 6953 -1 . 6937 -1	8. 088 8. 098 8. 109 8. 119 8. 129	$\begin{array}{ccccc} .4221 & ^{-2}\\ .4197 & ^{-2}\\ .4174 & ^{-2}\\ .4151 & ^{-2}\\ .4129 & ^{-2}\\ \end{array}$	207. 0 208. 1 209. 3 210. 5 211. 7	2. 362195 2. 362397 2. 362599 2. 362800 2. 363001	96. 233 96. 272 96. 312 96. 352 96. 391	7. 048 7. 039 7. 031 7. 022 7. 013	. 3924 . 3923 . 3923 . 3923 . 3922	77. 33 77. 52 77. 71 77. 90 78. 09	5. 580 5. 581 5. 582 5. 583 5. 584	13. 86 13. 89 13. 92 13. 95 13. 99	. 7805 -2 . 7762 -2 . 7719 -2 . 7677 -2 . 7634 -2	. 1163 -1 . 1160 -1 . 1157 -1 . 1155 -1 . 1152 -1
8. 20	.8723 -4	$\begin{array}{cccc} .1260 & -2 \\ .1253 & -2 \\ .1246 & -2 \\ .1239 & -2 \\ .1232 & -2 \\ \end{array}$	. 6921 -1	8. 139	. 4106 -2	212.8	2. 363201	96. 430	7. 005	. 3922	78. 28	5. 585	14. 02	.7592 -2	.1149 -1
8. 21	.8654 -4		. 6906 -1	8. 149	. 4083 -2	214.0	2. 363400	96. 470	6. 996	. 3921	78. 47	5. 586	14. 05	.7551 -2	.1146 -1
8. 22	.8586 -4		. 6890 -1	8. 159	. 4061 -2	215.2	2. 363598	96. 509	6. 988	. 3921	78. 66	5. 587	14. 08	.7509 -2	.1143 -1
8. 23	.8518 -4		. 6874 -1	8. 169	. 4039 -2	216.4	2. 363796	96. 548	6. 979	. 3921	78. 86	5. 588	14. 11	.7468 -2	.1141 -1
8. 24	.8451 -4		. 6859 -1	8. 179	. 4017 -2	217.7	2. 363993	96. 587	6. 971	. 3920	79. 05	5. 588	14. 15	.7427 -2	.1138 -1
8. 25	.8384 -4	. 1225 -2	. 6843 -1	8. 189	. 3995 -2	218. 9	2. 364190	96. 626	6. 962	. 3920	79. 24	5. 589	14. 18	.7386 -2	. 1135 -1
8. 26	.8318 -4	. 1218 -2	. 6828 -1	8. 199	. 3973 -2	220. 1	2. 364385	96. 665	6. 954	. 3920	79. 43	5. 590	14. 21	.7346 -2	. 1132 -1
8. 27	.8253 -4	. 1211 -2	. 6813 -1	8. 209	. 3951 -2	221. 3	2. 364581	96. 704	6. 945	. 3919	79. 63	5. 591	14. 24	.7306 -2	. 1130 -1
8. 28	.8188 -4	. 1205 -2	. 6797 -1	8. 219	. 3930 -2	222. 5	2. 364775	96. 742	6. 937	. 3919	79. 82	5. 592	14. 27	.7266 -2	. 1127 -1
8. 29	.8124 -4	. 1198 -2	. 6782 -1	8. 229	. 3908 -2	223. 8	2. 364969	96. 781	6. 928	. 3919	80. 01	5. 593	14. 31	.7226 -2	. 1124 -1
8. 30 8. 31 8. 32 8. 33 8. 34	.8060 -4 .7997 -4 .7935 -4 .7873 -4 .7811 -4	$\begin{array}{ccccc} .\ 1191 & -2 \\ .\ 1184 & -2 \\ .\ 1178 & -2 \\ .\ 1171 & -2 \\ .\ 1165 & -2 \\ \end{array}$	. 6767 -1 . 6752 -1 . 6737 -1 . 6721 -1 . 6706 -1	8. 240 8. 250 8. 260 8. 270 8. 280	. 3887 -2 . 3866 -2 . 3845 -2 . 3824 -2 . 3803 -2	225. 0 226. 3 227. 5 228. 8 230. 0	2. 365162 2. 365354 2. 365546 2. 365738 2. 365928	96. 820 96. 858 96. 896 96. 935 96. 973	6. 920 6. 912 6. 903 6. 895 6. 887	. 3918 . 3918 . 3918 . 3917 . 3917	80. 21 80. 40 80. 59 80. 79 80. 98	5. 594 5. 595 5. 596 5. 597 5. 598	14. 34 14. 37 14. 40 14. 44 14. 47	$\begin{array}{cccc} .7187 & ^{-2}\\ .7147 & ^{-2}\\ .7109 & ^{-2}\\ .7070 & ^{-2}\\ .7031 & ^{-2}\\ \end{array}$	.1122 -1 .1119 -1 .1116 -1 .1114 -1 .1111 -1
8. 35	. 7750 -4	$\begin{array}{ccccc} .1158 & ^{-2}\\ .1152 & ^{-2}\\ .1145 & ^{-2}\\ .1139 & ^{-2}\\ .1133 & ^{-2}\\ \end{array}$	. 6691 -1	8. 290	. 3783 -2	231. 3	2. 366118	97. 011	6. 878	. 3917	81. 18	5. 599	14. 50	. 6993 -2	. 1108 -1
8. 36	. 7690 -4		. 6676 -1	8. 300	. 3762 -2	232. 6	2. 366307	97. 049	6. 870	. 3917	81. 37	5. 599	14. 53	. 6955 -2	. 1106 -1
8. 37	. 7630 -4		. 6662 -1	8. 310	. 3742 -2	233. 9	2. 366496	97. 087	6. 862	. 3916	81. 57	5. 600	14. 57	. 6918 -2	. 1103 -1
8. 38	. 7571 -4		. 6647 -1	8. 320	. 3722 -2	235. 2	2. 366684	97. 125	6. 854	. 3916	81. 76	5. 601	14. 60	. 6880 -2	. 1100 -1
8. 39	. 7512 -4		. 6632 -1	8. 330	. 3702 -2	236. 5	2. 366871	97. 162	6. 845	. 3916	81. 96	5. 602	14. 63	. 6843 -2	. 1098 -1
8. 40	.7454 -4	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 6617 -1	8. 340	. 3682 -2	237. 8	2. 367058	97. 200	6. 837	. 3915	82. 15	5. 603	14. 66	. 6806 -2	. 1095 -1
8. 41	.7396 -4		. 6603 -1	8. 350	. 3662 -2	239. 1	2. 367244	97. 238.	6. 829	. 3915	82. 35	5. 604	14. 70	. 6769 -2	. 1093 -1
8. 42	.7339 -4		. 6588 -1	8. 360	. 3642 -2	240. 4	2. 367430	97. 276	6. 821	. 3915	82. 55	5. 605	14. 73	. 6733 -2	. 1090 -1
8. 43	.7282 -4		. 6573 -1	8. 370	. 3623 -2	241. 7	2. 367615	97. 313	6. 813	. 3914	82. 74	5. 606	14. 76	. 6697 -2	. 1087 -1
8. 44	.7226 -4		. 6559 -1	8. 381	. 3603 -2	243. 0	2. 367799	97. 350	6. 805	. 3914	82. 94	5. 606	14. 79	. 6661 -2	. 1085 -1

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## TABLE II.—SUPERSONIC FLOW—Continued

					1		1	1	1	1			1	1	1
$M$ or $M_1$	$\frac{p}{p_t}$	<u>ρ</u> ρι	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$rac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{\ell_2}}$
8. 45	.7170 -4	. 1096 -2	. 6544 -1	8, 791	. 3584 -2	244. 4	2. 367983	97. 388	6. 797	. 3914	83. 14	5. 607	14. 83	. 6625 -2	. 1082 -1
8. 46	.7115 -4	. 1090 -2	. 6530 -1	8, 401	. 3565 -2	245. 7	2. 368166	97. 424	6. 788	. 3913	83. 33	5. 608	14. 86	. 6589 -2	. 1080 -1
8. 47	.7060 -4	. 1084 -2	. 6515 -1	8, 411	. 3545 -2	247. 0	2. 368348	97. 462	6. 780	. 3913	83. 53	5. 609	14. 89	. 6554 -2	. 1077 -1
8. 48	.7006 -4	. 1078 -2	. 6501 -1	8, 421	. 3526 -2	248. 4	2. 368530	97. 499	6. 772	. 3913	83. 73	5. 610	14. 93	. 6519 -2	. 1075 -1
8. 49	.6952 -4	. 1072 -2	. 6487 -1	8, 431	. 3508 -2	249. 7	2. 368712	97. 536	6. 764	. 3912	83. 93	5. 611	14. 96	. 6484 -2	. 1072 -1
8. 50 8. 51 8. 52 8. 53 8. 54	6898 -4 6846 -4 6793 -4 6741 -4 6690 -4	$\begin{array}{cccc} .1066 & -2 \\ .1060 & -2 \\ .1054 & -2 \\ .1048 & -2 \\ .1043 & -2 \\ \end{array}$	. 6472 -1 . 6458 -1 . 6444 -1 . 6430 -1 . 6416 -1	8. 441 8. 451 8. 461 8. 471 8. 481	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	251. 1 252. 5 253. 8 255. 2 256. 6	2. 368892 2. 369072 2. 369252 2. 369431 2. 369609	97. 573 97. 609 97. 646 97. 683 97. 719	6. 756 6. 748 6. 740 6. 732 6. 725	. 3912 . 3912 . 3911 . 3911 . 3911	84. 13 84. 32 84. 52 84. 72 84. 92	5. 612 5. 613 5. 613 5. 614 5. 615	14. 99 15. 02 15. 06 15. 09 15. 12	. 6449 -2 . 6415 -2 . 6380 -2 . 6346 -2 . 6313 -2	. 1070 -1 . 1067 -1 . 1065 -1 . 1062 -1 . 1060 -1
8. 55 8. 56 8. 57 8. 58 8. 59	.6638 -4 .6588 -4 .6538 -4 .6488 -4 .6438 -4	$\begin{array}{cccc} .1037 & -2 \\ .1031 & -2 \\ .1026 & -2 \\ .1020 & -2 \\ .1015 & -2 \\ \end{array}$	. 6402 -1 . 6388 -1 . 6374 -1 . 6560 -1 . 6346 -1	8. 491 8. 501 8. 511 8. 522 8. 532	$\begin{array}{ccccc} .3397 & -2 \\ .3379 & -2 \\ .3361 & -2 \\ .3343 & -2 \\ .3326 & -2 \\ \end{array}$	258. 0 259. 4 260. 8 262. 2 263. 6	2. 369787 2. 369964 2. 370140 2. 370316 2. 370492	97. 756 97. 792 97. 828 97. 865 97. 901	6. 717 6. 709 6. 701 6. 693 6. 685	.3911 .3910 .3910 .3910 .3909	85. 12 85. 32 85. 52 85. 72 85. 92	5. 616 5. 617 5. 618 5. 618 5. 619	15. 16 15. 19 15. 22 15. 26 15. 29	.6279 -2 .6246 -2 .6212 -2 .6179 -2 .6147 -2	. 1057 -1 . 1055 -1 . 1052 -1 . 1050 -1 . 1048 -1
8. 60	.6390 -4	. 1009 -2	. 6332 -1	8. 542	$\begin{array}{ccccc} .3308 & ^{-2}\\ .3291 & ^{-2}\\ .3273 & ^{-2}\\ .3256 & ^{-2}\\ .3239 & ^{-2} \end{array}$	265. 0	2. 370667	97, 937	6 677	. 3909	86. 12	5. 620	15. 32	.6114 -2	. 1045 -1
8. 61	.6341 -4	. 1004 -2	. 6319 -1	8. 552		266. 4	2 370841	97, 973	6 670	. 3909	86. 32	5. 621	15. 36	.6082 -2	. 1043 -1
8. 62	.6293 -4	. 9981 -3	. 6305 -1	8. 562		267. 9	2. 371015	98, 009	6 662	. 3909	86. 52	5. 622	15. 39	.6050 -2	. 1040 -1
8. 63	.6245 -4	. 9927 -3	. 6291 -1	8. 572		269. 3	2. 371188	93, 045	6 654	. 3908	86. 72	5. 623	15. 42	.6013 -2	. 1038 -1
8. 64	.6198 -4	. 9873 -3	. 6277 -1	8. 582		270. 8	2. 371360	98, 081	6 646	. 3908	86. 92	5. 623	15. 46	.5986 -2	. 1035 -1
8. 65	.6151 -4	. 9820 -3	. 6264 -1	8. 592	.3222 -2	272. 2	2. 371532	98. 116	6. 639	. 3908	87. 13	5. 624	15. 49	. 5954 -2	.1033 -1
8. 66	.6105 -4	. 9767 -3	. 6250 -1	8. 602	.3205 -2	273. 7	2. 371704	98. 152	6. 631	. 3907	87. 33	5. 625	15. 53	. 5923 -2	.1031 -1
8. 67	.6059 -4	. 9714 -3	. 6237 -1	8. 612	.3188 -2	275. 1	2. 371875	98. 187	6. 623	. 3907	87. 53	5. 626	15. 56	. 5892 -2	.1028 -1
8. 68	.6013 -4	. 9662 -3	. 6223 -1	8. 622	.3171 -2	276. 6	2. 372045	98. 223	6. 616	. 3907	87. 73	5. 627	15. 59	. 5861 -2	.1026 -1
8. 69	.5968 -4	. 9610 -3	. 6210 -1	8. 632	.3155 -2	278. 1	2. 372215	98. 258	6. 608	. 3906	87. 94	5. 627	15. 63	. 5830 -2	.1024 -1
8. 70	.5923 -4	$\begin{array}{ccccc} .9558 & ^{-3} \\ .9507 & ^{-3} \\ .9456 & ^{-3} \\ .9405 & ^{-3} \\ .9355 & ^{-3} \end{array}$	.6197 -1	8. 642	. 3138 -2	279. 6	2. 372384	98. 293	6. 600	. 3906	88. 14	5. 628	15, 66	.5799 -2	.1021 -1
8. 71	.5878 -4		.6183 -1	8. 652	. 3122 -2	281. 1	2. 372553	98. 329	6. 593	. 3906	88. 34	5. 629	15, 69	.5769 -2	.1019 -1
8. 72	.5834 -4		.6170 -1	8. 662	. 3105 -2	282. 6	2. 372721	98. 364	6. 585	. 3906	88. 54	5. 630	15, 73	.5739 -2	.1017 -1
8. 73	.5790 -4		.6157 -1	8. 673	. 3089 -2	284. 1	2. 372889	98. 399	6. 578	. 3905	88. 75	5. 631	15, 76	.5709 -2	.1014 -1
8. 74	.5747 -4		.6143 -1	8. 683	. 3073 -2	285. 6	2. 373056	98. 434	6. 570	. 3905	88. 95	5. 631	15, 80	.5679 -2	.1012 -1
8. 75	.5704 -4	$\begin{array}{ccccc} .9305 & -3 \\ .9255 & -3 \\ .9205 & -3 \\ .9156 & -3 \\ .9108 & -3 \\ \end{array}$	.6130 -1	8. 693	.3057 -2	287. 1	2. 373222	98. 469	6. 562	. 3905	89. 16	5. 632	15. 83	. 5649 -2	. 1010 -1
8. 76	.5661 -4		.6117 -1	8. 703	.3041 -2	288. 6	2. 373388	98. 504	6. 555	. 3904	89. 36	5. 633	15. 86	. 5620 -2	. 1007 -1
8. 77	.5619 -4		.6104 -1	8. 713	.3025 -2	290. 1	2. 373554	98. 539	6. 547	. 3904	89. 57	5. 634	15. 90	. 5590 -2	. 1005 -1
8. 78	.5577 -4		.6091 -1	8. 723	.3010 -2	291. 7	2. 373719	98. 573	6. 540	. 3904	89. 77	5. 635	15. 93	. 5561 -2	. 1003 -1
8. 79	.5536 -4		.6078 -1	8. 733	.2994 -2	293. 2	2. 373883	98. 608	6. 532	. 3904	89. 97	5. 635	15. 97	. 5532 -2	. 1001 -1
8. 80	.5494 -4	. 9059 -3	. 6065 -1	8. 743	. 2978 -2	294. 8	2. 374047	98, 642	6. 525	. 3903	90. 18	5. 636	16. 00	.5504 -2	. 9983 -2
8. 81	.5453 -4	. 9011 -3	. 6052 -1	8. 753	. 2963 -2	296. 3	2. 374210	98, 677	6. 518	. 3903	90. 39	5. 637	16. 04	.5475 -2	. 9960 -2
8. 82	.5413 -4	. 8963 -3	. 6039 -1	8. 763	. 2948 -2	297. 9	2. 374373	98, 711	6. 510	. 3903	90. 59	5. 638	16. 07	.5447 -2	. 9938 -2
8. 83	.5373 -4	. 8915 -3	. 6026 -1	8. 773	. 2932 -2	299. 5	2. 374535	98, 745	6. 503	. 3903	90. 80	5. 638	16. 10	.5418 -2	. 9916 -2
8. 84	.5333 -4	. 8868 -3	. 6014 -1	8. 783	. 2917 -2	301. 0	2. 374697	98, 780	6. 495	. 3902	91. 00	5. 639	16. 14	.5390 -2	. 9893 -2
8. 85	. 5293 -4	. 8821 -3	.6001 -1	8. 793	. 2902 -2	302. 6	2. 374859	98. 814	6, 488	.3902	91, 21	5. 640	16. 17	.5362 -2	. 9871 -2
8. 86	. 5254 -4	. 8774 -3	.5988 -1	8. 803	. 2887 -2	304. 2	2. 375019	98. 848	6, 481	.3902	91, 42	5. 641	16. 21	.5335 -2	. 9849 -2
8. 87	. 5215 -4	. 8728 -3	.5975 -1	8. 813	. 2872 -2	305. 8	2. 375180	98. 882	6, 473	.3901	91, 62	5. 641	16. 24	.5307 -2	. 9827 -2
8. 88	. 5177 -4	. 8682 -3	.5963 -1	8. 824	. 2857 -2	307. 4	2. 375339	98. 916	6, 466	.3901	91, 83	5. 642	16. 28	.5280 -2	. 9805 -2
8. 89	. 5139 -4	. 8636 -3	.5950 -1	8. 834	. 2843 -2	309. 0	2. 375499	98. 950	6, 459	.3901	92, 04	5. 643	16. 31	.5253 -2	. 9783 -2
8. 90	.5101 -4	.8590 -3	. 5938 -1	8. 844	. 2828 -2	310. 6	2. 375657	98, 984	6. 451	. 3901	92. 25	5. 644	16. 35	. 5226 -2	. 9761 -2
8. 91	.5063 -4	.8545 -3	. 5925 -1	8. 854	. 2814 -2	312. 3	2. 375816	99, 018	6. 444	. 3900	92. 45	5. 645	16. 38	. 5199 -2	. 9739 -2
8. 92	.5026 -4	.8500 -3	. 5913 -1	8. 864	. 2799 -2	313. 9	2. 375973	99, 051	6. 437	. 3900	92. 66	5. 645	16. 41	. 5172 -2	. 9718 -2
8. 93	.4989 -4	.8456 -3	. 5900 -1	8. 874	. 2785 -2	315. 5	2. 376131	99, 085	6. 430	. 3900	92. 87	5. 646	16. 45	. 5145 -2	. 9696 -2
8. 94	.4952 -4	.8411 -3	. 5888 -1	8. 884	. 2771 -2	317. 2	2. 376287	99, 119	6. 422	. 3900	93. 08	5. 647	16. 48	. 5119 -2	. 9675 -2
8. 95	.4916 -4	.8367 -3	. 5875 -1	8. 894	. 2756 -2	318. 8	2. 376444	99. 152	6. 415	. 3899	93. 29	5. 647	16. 52	. 5093 -2	. 9653 -2
8. 96	.4880 -4	.8323 -3	. 5863 -1	8. 904	. 2742 -2	320. 5	2. 376599	99. 186	6. 408	. 3899	93. 50	5. 648	16. 55	. 5067 -2	. 9631 -2
8. 97	.4844 -4	.8280 -3	. 5851 -1	8. 914	. 2728 -2	322. 1	2. 376755	99. 219	6. 401	. 3899	93. 70	5. 649	16. 59	. 5041 -2	. 9610 -2
8. 98	.4809 -4	.8236 -3	. 5838 -1	8. 924	. 2714 -2	323. 8	2. 376909	99. 252	6. 394	. 3899	93. 91	5. 650	16. 62	. 5015 -2	. 9589 -2
8. 99	.4773 -4	.8193 -3	. 5826 -1	8. 934	. 2701 -2	325. 5	2. 377064	99. 286	6. 387	. 3898	94. 12	5. 650	16. 66	. 4989 -2	. 9567 -2
9. 00	.4739 -4	.8150 -3	. 5814 -1	8. 944	$\begin{array}{ccccc} .\ 2687 & -2 \\ .\ 2673 & -2 \\ .\ 2660 & -2 \\ .\ 2646 & -2 \\ .\ 2633 & -2 \end{array}$	327. 2	2. 377217	99. 319	6. 379	. 3898	94, 33	5. 651	16. 69	. 4964 -2	. 9546 -2
9. 01	.4704 -4	.8108 -3	. 5802 -1	8. 954		328. 9	2. 377371	99. 352	6. 372	. 3898	94, 54	5. 652	16. 73	. 4939 -2	. 9525 -2
9. 02	.4670 -4	.8066 -3	. 5790 -1	8. 964		330. 6	2. 377524	99. 384	6. 365	. 3897	94, 75	5. 653	16. 76	. 4913 -2	. 9504 -2
9. 03	.4636 -4	.8024 -3	. 5778 -1	8. 974		332. 3	2. 377676	99. 417	6. 358	. 3897	94, 96	5. 653	16. 80	. 4888 -2	. 9483 -2
9. 04	.4602 -4	.7982 -3	. 5766 -1	8. 985		334. 0	2. 377828	99. 451	6. 351	. 3897	95, 18	5. 654	16. 83	. 4864 -2	. 9462 -2
9. 05 9. 06 9. 07 9. 08 9. 09	. 4569 -4 . 4535 -4 . 4503 -4 . 4470 -4 . 4438 -4	. 7940 -3 . 7899 -3 . 7858 -3 . 7818 -3 . 7777 -3	. 5754 -1 . 5742 -1 . 5730 -1 . 5718 -1 . 5706 -1	8. 995 9. 005 9. 015 9. 025 9. 035	$\begin{array}{cccc} .2619 & -2 \\ .2606 & -2 \\ .2593 & -2 \\ .2580 & -2 \\ .2567 & -2 \end{array}$	335. 7 337. 5 339. 2 340. 9 342. 7	2. 377979 2. 378130 2. 378281 2. 378431 2. 378580	99. 483 99. 516 99. 549 99. 581 99. 614	6. 344 6. 337 6. 330 6. 323 6. 316	.3897 .3896 .3896 .3896 .3896	95, 39 95, 60 95, 81 96, 02 96, 23	5. 655 5. 656 5. 656 5. 657 5. 658	16. 87 16. 90 16. 94 16. 97 17. 01	. 4839 -2 . 4814 -2 . 4790 -2 . 4766 -2 . 4742 -2	$\begin{array}{ccccc} .9441 & -2 \\ .9421 & -2 \\ .9400 & -2 \\ .9380 & -2 \\ .9359 & -2 \\ \end{array}$
9. 10 9. 11 9. 12 9. 13 9. 14	. 4405 -4 . 4374 -4 . 4342 -4 . 4311 -4 . 4280 -4	.7737 -3 .7697 -3 .7657 -3 .7618 -3 .7578 -3	. 5694 -1 . 5682 -1 . 5671 -1 . 5659 -1 . 5647 -1	9. 045 9. 055 9. 065 9. 075 9. 085	$\begin{array}{ccccc} .2554 & -2 \\ .2541 & -2 \\ .2528 & -2 \\ .2515 & -2 \\ .2503 & -2 \\ \end{array}$	344. 5 346. 2 348. 0 349. 8 351. 6	2. 378729 2. 378878 2. 379026 2. 379174 2. 379321	99. 646 99. 679 99. 711 99. 743 99. 775	6. 309 6. 302 6. 295 6. 288 6. 281	. 3895 . 3895 . 3895 . 3895 . 3894	96. 45 96. 66 96. 87 97. 08 97. 30	5. 658 5. 659 5. 660 5. 660 5. 661	17. 05 17. 08 17. 12 17. 15 17. 19	$\begin{array}{ccccc} .4718 & -2 \\ .4694 & -2 \\ .4670 & -2 \\ .4646 & -2 \\ .4623 & -2 \\ \end{array}$	. 9338 -2 . 9318 -2 . 9298 -2 . 9277 -2 . 9257 -2
9. 15 9. 16 9. 17 9. 18 9. 19	. 4249 -4 . 4218 -4 . 4188 -4 . 4158 -4 . 4128 -4	.7539 -3 .7501 -3 .7462 -3 .7424 -3 .7386 -3	. 5636 -1 . 5624 -1 . 5612 -1 . 5601 -1 . 5589 -1	9. 095 9. 105 9. 115 9. 125 9. 135	. 2490 -2 . 2478 -2 . 2465 -2 . 2453 -2 . 2441 -2	353, 4 355, 2 357, 0 358, 8 360, 6	2, 379468 2, 379614 2, 379760 2, 379905 2, 380050	99. 807 99. 840 99. 872 99. 904 99. 936	6. 274 6. 268 6. 261 6. 254 6. 247	. 3894 . 3894 . 3893 . 3893	97. 51 97. 72 97. 94 98. 15 98. 37	5. 662 5. 663 5. 663 5. 664 5. 665	17. 22 17. 26 17. 29 17. 33 17. 37	. 4600 -2 . 4577 -2 . 4554 -2 . 4531 -2 . 4508 -2	. 9237 -2 . 9217 -2 . 9197 -2 . 9177 -2 . 9158 -2
9. 20	. 4099 -4	. 7348 -3	. 5578 -1	9. 145	. 2428 -2	362. 5	2. 380195	99. 967	6. 240	. 3893	98. 58	5. 665	17. 40	. 4486 -2	. 9138 -2
9. 21	. 4069 -4	. 7310 -3	. 5566 -1	9. 156	. 2416 -2	364. 3	2. 380339	99. 999	6. 233	. 3893	98. 79	5. 666	17. 44	. 4463 -2	. 9118 -2
9. 22	. 4040 -4	. 7273 -3	. 5555 -1	9. 166	. 2404 -2	366. 2	2. 380483	100. 031	6. 227	. 3892	99. 01	5. 667	17. 47	. 4441 -2	. 9098 -2
9. 23	. 4011 -4	. 7236 -3	. 5544 -1	9. 176	. 2392 -2	368. 0	2. 380626	100. 062	6. 220	. 3892	99. 23	5. 667	17. 51	. 4419 -2	. 9078 -2
9. 24	. 3983 -4	. 7199 -3	. 5532 -1	9. 186	. 2380 -2	369. 9	2. 380769	100. 094	6. 213	. 3892	99. 44	5. 668	17. 54	. 4397 -2	. 9059 -2
9. 25	.3954 -4	.7162 -3	. 5521 -1	9. 196	. 2368 -2	371. 7	2. 380911	100. 125	6. 206	. 3892	99, 66	5. 669	17. 58	. 4375 -2	. 9040 -2
9. 26	.3926 -4	.7126 -3	. 5510 -1	9. 206	. 2357 -2	373. 6	2. 381053	100. 157	6. 200	. 3892	99, 87	5. 669	17. 62	. 4353 -2	. 9020 -2
9. 27	.3898 -4	.7090 -3	. 5499 -1	9. 216	. 2345 -2	375. 5	2. 381194	100. 188	6. 193	. 3891	100, 1	5. 670	17. 65	. 4331 -3	. 9000 -2
9. 28	.3871 -4	.7054 -3	. 5487 -1	9. 226	. 2333 -2	377. 4	2. 381335	100. 219	6. 186	. 3891	100, 3	5. 671	17. 69	. 4310 -2	. 8981 -2
9. 29	.3843 -4	.7018 -3	. 5476 -1	9. 236	. 2322 -2	379. 3	2. 381476	100. 251	6. 179	. 3891	100, 5	5. 671	17. 72	. 4288 -2	. 8962 -2
9. 30	. 3816 -4	. 6982 -3	. 5465 -1	9. 246	$\begin{array}{cccc} .2310 & -2 \\ .2299 & -2 \\ .2287 & -2 \\ .2276 & -2 \\ .2265 & -2 \end{array}$	381. 2	2. 381616	100. 282	6. 173	.3891	100. 7	5. 672	17. 76	. 4267 -2	. 8943 -2
9. 31	. 3789 -4	. 6947 -3	. 5454 -1	9. 256		383. 1	2. 381756	100. 313	6. 166	.3890	101. 0	5. 673	17. 80	. 4246 -2	. 8924 -2
9. 32	. 3762 -4	. 6912 -3	. 5443 -1	9. 266		385. 1	2. 381895	100. 344	6. 160	.3890	101. 2	5. 673	17. 83	. 4225 -2	. 8904 -2
9. 33	. 3735 -4	. 6877 -3	. 5432 -1	9. 276		387. 0	2. 382034	100. 375	6. 153	.3890	101. 4	5. 674	17. 87	. 4204 -2	. 8885 -2
9. 34	. 3709 -4	. 6842 -3	. 5421 -1	9. 286		389. 0	2. 382173	100. 406	6. 146	.3890	101. 6	5. 675	17. 91	. 4183 -2	. 8867 -2

## EQUATIONS. TABLES, AND CHARTS FOR COMPRESSIBLE FLOW

#### TABLE II.—SUPERSONIC FLOW—Continued

	$\gamma = 7/5$														
$egin{array}{c} M \  ext{or} \ M_1 \end{array}$	$\frac{p}{p_i}$	$\frac{\rho}{\rho_t}$	$\left  rac{T}{T_t}  ight $	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{oldsymbol{T_2}}{oldsymbol{T_1}}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
9. 35 9. 36 9. 37 9. 38 9. 39	. 3683 -4 . 3657 -4 . 3631 -4 . 3605 -4 . 3580 -4	.6807 -3 .6773 -3 .6739 -3 .6705 -3 .6671 -3	. 5410 -1 . 5399 -1 . 5388 -1 . 5377 -1 . 5366 -1	9. 296 9. 306 9. 316 9. 327 9. 337	$\begin{array}{cccc} .2254 & -2 \\ .2243 & -2 \\ .2232 & -2 \\ .2221 & +2 \\ .2210 & -2 \\ \end{array}$	390, 9 392, 9 394, 8 396, 8 398, 8	2. 382311 2. 382448 2. 382585 2. 382722 2. 382859	100, 436 100, 467 100, 498 100, 529 100, 559	6. 140 6. 133 6. 127 6. 120 6. 113	.3889 .3889 .3889 .3889 .3888	101. 8 102. 0 102. 3 102. 5 102. 7	5. 675 5. 676 5. 677 5. 677 5. 678	17. 94 17. 98 18. 01 18. 05 18. 09	. 4162 -2 . 4142 -2 . 4121 -2 . 4101 -2 . 4081 -2	. 8849 -2 . 8828 -2 . 8809 -2 . 8791 -2 . 8773 -2
9. 40 9. 41 9. 42 9. 43 9. 44	.3555 -4 .3530 -4 .3505 -4 .3481 -4 .3456 -4	.6638 -3 $.6604 -3$ $.6571 -3$ $.6538 -3$ $.6506 -3$	.5356 -1 .5345 -1 .5334 -1 .5323 -1 .5313 -1	9. 347 9. 357 9. 367 9. 377 9. 387	$\begin{array}{cccc} .2199 & -2 \\ .2188 & -2 \\ .2177 & -2 \\ .2167 & -2 \\ .2156 & -2 \\ \end{array}$	400. 8 402. 8 404. 8 406. 8 408. 8	2. 382995 2. 383130 2. 383265 2. 383400 2. 383534	100, 590 100, 620 100, 651 100, 681 100, 711	6. 107 6. 100 6. 094 6. 087 6. 081	.3888 .3888 .3888 .3888 .3887	102. 9 103. 1 103. 4 103. 6 103. 8	5. 679 5. 679 5. 680 5. 681 5. 681	18. 12 18. 16 18. 20 18. 23 18. 27	$\begin{array}{cccc} .4061 & -2 \\ .4041 & -2 \\ .4021 & -2 \\ .4001 & -2 \\ .3982 & -2 \end{array}$	. 8754 -2 . 8736 -2 . 8718 -2 . 8699 -2 . 8681 -2
9. 45 9. 46 9. 47 9. 48 9. 49	.3432 -4 .3408 -4 .3384 -4 .3361 -4 .3337 -4	.6473 -3 .6441 -3 .6409 -3 .6377 -3 .6345 -3	. 5302 -1 . 5291 -1 . 5281 -1 . 5270 -1 . 5260 -1	9. 397 9. 407 9. 417 9. 427 9. 437	$\begin{array}{cccc} .2146 & -2 \\ .2135 & -2 \\ .2125 & -2 \\ .2114 & -2 \\ .2104 & -2 \\ \end{array}$	410. 9 412. 9 414. 9 417. 0 419. 1	2, 383668 2, 383802 2, 383935 2, 384068 2, 384200	100. 742 100. 772 100. 802 100. 832 100. 862	6, 074 6, 068 6, 062 6, 055 6, 049	.3887 .3887 .3887 .3886 .3886	104. 0 104. 2 104. 5 104. 7 104. 9	5. 682 5. 683 5. 683 5. 684 5. 684	18. 31 18. 34 18. 38 18. 42 18. 45	$\begin{array}{ccccc} .3962 & -2 \\ .3943 & -2 \\ .3924 & -2 \\ .3904 & -2 \\ .3885 & -2 \end{array}$	. 8662 -2 . 8644 -2 . 8626 -2 . 8607 -2 . 8589 -2
9. 50 9. 51 9. 52 9. 53 9. 54	.3314 -4 .3291 -4 .3268 -4 .3246 -4 .3223 -4	.6313 -3 .6282 -3 .6251 -3 .6220 -3 .6189 -3	.5249 -1 .5239 -1 .5228 -1 .5218 -1 .5208 -1	9. 447 9. 457 9. 467 9. 477 9. 487	. 20942 . 20842 . 20732 . 20632 . 20532	421. 1 423. 2 425. 3 427. 4 429. 5	2. 384332 2. 384464 2. 384595 2. 384726 2. 384856	100. 892 100. 922 100. 952 100. 981 101. 011	6. 042 6. 036 6. 030 6. 023 6. 017	. 3886 . 3886 . 3886 . 3885 . 3885	105. 1 105. 3 105. 6 105. 8 106. 0	5, 685 5, 686 5, 686 5, 687 5, 688	18. 49 18. 53 18. 57 18. 60 18. 64	.3866 -2 .3848 -2 .3829 -2 .3810 -2 .3792 -2	. 8572 -2 . 8554 -2 . 8536 -2 . 8518 -2 . 8500 -2
9, 55 9, 56 9, 57 9, 58 9, 59	.3201 -4 .3179 -4 .3157 -4 .3135 -4 .3113 -4	.6158 -3 .6128 -3 .6098 -3 .6067 -3 .6037 -3	. 5197 -1 . 5187 -1 . 5177 -1 . 5167 -1 . 5156 -1	9. 498 9. 508 9. 518 9. 528 9. 538	$\begin{array}{ccccc} .2043 & -2 \\ .2034 & -2 \\ .2024 & -2 \\ .2014 & -2 \\ .2004 & -2 \\ \end{array}$	431. 6 433. 7 435. 9 438. 0 440. 2	2. 384986 2. 385116 2. 385245 2. 385374 2. 385502	101. 041 101. 070 101. 100 101. 129 101. 159	6. 011 6. 004 5. 998 5. 992 5. 985	. 3885 . 3885 . 3884 . 3884 . 3884	106. 2 106. 5 106. 7 106. 9 107. 1	5. 688 5. 689 5. 689 5. 690 5. 691	18. 68 18. 71 18. 75 18. 79 18. 83	.3773 -2 .3755 -2 .3737 -2 .3719 -2 .3701 -2	.8483 -2 .8465 -2 .8447 -2 .8431 -2 .8412 -2
9. 60 9. 61 9. 62 9. 63 9. 64	. 3092 -4 . 3070 -4 . 3049 -4 . 3028 -4 . 3007 -4	. 6008 -3 . 5978 -3 . 5949 -3 . 5919 -3 . 5890 -3	. 5146 -1 . 5136 -1 . 5126 -1 . 5116 -1 . 5106 -1	9, 548 9, 558 9, 568 9, 578 9, 588	. 1995 -2 . 1985 -2 . 1975 -2 . 1966 -2 . 1956 -2	442. 3 444. 5 446. 7 448. 8 451. 0	2. 385630 2. 385758 2. 385885 2. 386012 2. 386139	101, 188 101, 217 101, 247 101, 276 101, 305	5. 979 5. 973 5. 967 5. 960 5. 954	. 3884 . 3884 . 3883 . 3883 . 3883	107. 4 107. 6 107. 8 108. 0 108. 3	5. 691 5. 692 5. 692 5. 693 5. 694	18. 86 18. 90 18. 94 18. 98 19. 01	.3683 -2 .3665 -2 .3647 -2 .3630 -2 .3612 -2	.8394 -2 .8378 -2 .8360 -2 .8343 -2 .8325 -2
9, 65 9, 66 9, 67 9, 68 9, 69	. 2987 -4 . 2966 -4 . 2946 -4 . 2926 -4 . 2906 -4	. 5861 -3 . 5833 -3 . 5804 -3 . 5776 -3 . 5747 -3	. 5096 -1 . 5086 -1 . 5076 -1 . 5066 -1 . 5056 -1	9, 598 9, 608 9, 618 9, 628 9, 638	. 1947 -2 . 1938 -2 . 1928 -2 . 1919 -2 . 1910 -2	453. 2 455. 4 457. 7 459. 9 462. 1	2, 386265 2, 386391 2, 386516 2, 386641 2, 386766	101, 334 101, 363 101, 392 101, 421 101, 450	5. 948 5. 942 5. 936 5. 930 5. 923	. 3883 . 3883 . 3882 . 3882 . 3882	108. 5 108. 7 108. 9 109. 2 109. 4	5. 694 5. 695 5. 695 5. 696 5. 697	19. 05 19. 09 19. 13 19. 16 19. 20	.3595 -2 .3578 -2 .3560 -2 .3543 -2 .3526 -2	.8308 -2 .8291 -2 .8275 -2 .8257 -2 .8240 -2
9. 70 9. 71 9. 72 9. 73 9. 74	. 2886 -4 . 2866 -4 . 2847 -4 . 2827 -4 . 2808 -4	. 5719 -3 . 5691 -3 . 5664 -2 . 5636 -3 . 5609 -3	.5046 -1 .5036 -1 .5026 -1 .5016 -1 .5007 -1	9. 648 9. 658 9. 668 9. 678 9. 689	. 1901 -2 . 1892 -2 . 1883 -2 . 1874 -2 . 1865 -2	464. 4 466. 6 468. 9 471. 2 473. 4	2. 386890 2. 387014 2. 387138 2. 387261 2. 387384	101. 479 101. 507 101. 536 101. 564 101. 593	5, 917 5, 911 5, 905 5, 899 5, 893	.3882 .3882 .3881 .3881 .3881	109. 6 109. 8 110. 1 110. 3 110. 5	5. 697 5. 698 5. 698 5. 699 5. 700	19. 24 19. 28 19. 31 19. 35 19. 39	. 3510 -2 . 3493 -2 . 3476 -2 . 3459 -2 . 3443 -2	.8224 -2 .8206 -2 .8190 -2 .8174 -2 .8155 -2
9. 75 9. 76 9. 77 9. 78 9. 79	. 2789 -4 . 2770 -4 . 2751 -4 . 2733 -4 . 2714 -4	.5581 -3 .5554 -3 .5527 -3 .5501 -3 .5474 -3	4997 -1 4987 -1 4977 -1 4968 -1 4958 -1	9. 699 9. 709 9. 719 9. 729 9. 739	. 1856 -2 . 1847 -2 . 1838 -2 . 1830 -2 . 1821 -2	475. 7 478. 0 480. 3 482. 6 485. 0	2. 387507 2. 387629 2. 387751 2. 387872 2. 387993	101. 621 101. 650 101. 678 101. 707 101. 735	5, 887 5, 881 5, 875 5, 869 5, 863	. 3881 . 3880 . 3880 . 3880 . 3880	110. 7 111. 0 111. 2 111. 4 111. 7	5. 700 5. 701 5. 701 5. 702 5. 703	19. 43 19. 47 19. 50 19. 54 19. 58	.3427 -2 .3410 -2 .3394 -2 .3378 -2 .3362 -2	.8139 -2 .8123 -2 .8107 -2 .8090 -2 .8073 -2
9.80 9.81 9.82 9.83 9.84	. 2696 -4 . 2677 -4 . 2659 -4 . 2641 -4 . 2624 -4	. 5447 -3 . 5421 -3 . 5395 -3 . 5369 -3 . 5343 -3	. 4949 -1 . 4939 -1 . 4929 -1 . 4920 -1 . 4910 -1	9. 749 9. 759 9. 769 9. 779 9. 789	. 1812 -2 . 1804 -2 . 1795 -2 . 1787 -2 . 1778 -2	487. 3 489. 6 492. 0 494. 4 496. 7	2. 388114 2. 388234 2. 388354 2. 388474 2. 388593	101. 763 101. 791 101. 820 101. 848 101. 876	5. 857 5. 851 5. 845 5. 839 5. 833	. 3880 . 3879 . 3879 . 3879 . 3879	111. 9 112. 1 112. 3 112. 6 112. 8	5. 703 5. 704 5. 704 5. 705 5. 705	19. 62 19. 66 19. 69 19. 73 19. 77	.3346 -2 .3330 -2 .3314 -2 .3298 -2 .3283 -2	. 8057 -2 . 8040 -2 . 8025 -2 . 8008 -2 . 7992 -2
9. 85 9. 86 9. 87 9. 88 9. 89	. 2606 -4 . 2588 -4 . 2571 -4 . 2554 -4 . 2537 -4	. 5317 -3 . 5292 -3 . 5266 -3 . 5241 -3 . 5216 -3	. 4901 -1 . 4891 -1 . 4882 -1 . 4873 -1 . 4863 -1	9.819 9.829	. 1770 -2 . 1762 -2 . 1753 -2 . 1745 -2 . 1737 -2	499. 1 501. 5 503. 9 506. 3 508. 7	2. 388712 2. 388831 2. 388949 2 389067 2. 389185	101. 904 101. 932 101. 960 101. 987 102. 015	5. 827 5. 821 5. 815 5. 809 5. 803	. 3879 . 3878 . 3878 . 3878 . 3878	113. 0 113. 3 113. 5 113. 7 113. 9	5. 706 5. 707 5. 707 5. 708 5. 708	19. 81 19. 85 19. 89 19. 92 19. 96	.3267 -2 .3252 -2 .3237 -2 .3221 -2 .3206 -2	.7977 -2 .7960 -2 .7944 -2 .7928 -2 .7912 -2
9. 90 9. 91 9. 92 9. 93 9. 94	. 2520 -4 . 2503 -4 . 2486 -4 . 2469 -4 . 2453 -4	. 5166 -3 . 5141 -3 . 5117 -3	. 4854 -1 . 4845 -1 . 4835 -1 . 4826 -1 . 4817 -1	9. 869 9. 880	. 1729 -2 . 1720 -2 . 1712 -2 . 1704 -2 . 1696 -2	511. 2 513. 6 516. 0 518. 5 521. 0	2. 389302 2. 389419 2. 389536 2. 389652 2. 389768	102. 043 102. 070 102. 098 102. 126 102. 153	5. 797 5. 792 5. 786 5. 780 5. 774	.3878 .3877 .3877 .3877 .3877	114. 2 114. 4 114. 6 114. 9 115. 1	5. 709 5. 709 5. 710 5. 710 5. 711	20. 00 20. 04 20. 08 20. 12 20. 15	.3191 -2 .3176 -2 .3161 -2 .3146 -2 .3132 -2	. 7896 -2 . 7880 -2 . 7864 -2 . 7848 -2 . 7831 -2
9. 95 9. 96 9. 97 9. 98 9. 99	. 2436 -4 . 2420 -4 . 2404 -4 . 2388 -4 . 2372 -4	. 5020 -3 . 4996 -3	. 4780 -1	9. 920 9. 930	. 1689 -2 . 1681 -2 . 1673 -2 . 1665 -2 . 1657 -2	523. 4 525. 9 528. 4 530. 9 533. 4	2. 389884 2. 389999 2. 390114 2. 390229 2. 390343	102. 180 102. 208 102. 235 102. 262 102. 290	5. 768 5. 762 5. 756 5. 751 5. 745	.3877 .3877 .3876 .3876 .3876	115. 3 115. 6 115. 8 116. 0 116. 3	5. 712 5. 712 5. 713 5. 713 5. 714	20. 19 20. 23 20. 27 20. 31 20. 35	.3117 -2 .3102 -2 .3088 -2 .3073 -2 .3059 -2	
10.00 10.02 10.04 10.06 10.08	.2356 -4 .2325 -4 .2294 -4 .2264 -4 .2234 -4	.4901 -3 .4855 -3 .4809 -3	. 4708 -1	9, 970 9, 990 10, 01	. 1649 -2 . 1634 -2 . 1619 -2 . 1604 -2 . 1589 -2	535. 9 541. 0 546. 1 551. 3 556. 4	2. 390457 2. 390684 2. 390910 2. 391134 2. 391358	102. 32 102. 37 102. 42 102. 48 102. 53	5. 739 5. 728 5. 716 5. 705 5. 693	. 3876 . 3875 . 3875 . 3875 . 3874	116. 5 117. 0 117. 4 117. 9 118. 4	5. 714 5. 715 5. 717 5. 718 5. 719	20. 39 20. 47 20. 54 20. 62 20. 70	. 3045 -2 . 3016 -2 . 2988 -2 . 2961 -2 . 2934 -2	. 7678 -2 . 7646 -2 . 7616 -2
10. 10 10. 12 10. 14 10. 16 10. 18	. 2205 -4 . 2176 -4 . 2148 -4 . 2120 -4 . 2092 -4	. 4675 -3 . 4631 -3 . 4588 -3	. 4655 -1 . 4637 -1 . 4620 -1	10. 09 10. 11	. 1575 -2 . 1560 -2 . 1546 -2 . 1532 -2 . 1518 -2	561. 7 567. 0 572. 3 577. 6 583. 0	2. 391579 2. 391800 2. 392020 2. 392238 2. 392455	102. 59 102. 64 102. 70 102. 75 102. 80	5. 682 5. 671 5. 660 5. 648 5. 637	. 3874 . 3874 . 3873 . 3873 . 3872	118. 9 119. 3 119. 8 120. 3 120. 7	5. 720 5. 721 5. 722 5. 723 5. 724	20. 78 20. 86 20. 94 21. 01 21. 09	. 2906 -2 . 2879 -2 . 2853 -2 . 2827 -2 . 2801 -2	.7528 -2 .7498 -2 .7469 -2
10. 20 10. 22 10. 24 10. 26 10. 28	. 2011 -4	. 4461 -3 . 4419 -3 . 4378 -3	. 4568 -1 . 4551 -1 . 4534 -1	10. 17 10. 19 10. 21	$\begin{array}{c} .1504 & -2 \\ .1490 & -2 \\ .1476 & -2 \\ .1463 & -2 \\ .1450 & -2 \end{array}$	588. 4 593. 9 599. 5 605. 0 610. 6	2. 392670 2. 392885 2. 393098 2. 393310 2. 393521	102. 85 102. 90 102. 95 103. 01 103. 06	5. 626 5. 615 5. 604 5. 593 5. 582	. 3872 . 3872 . 3871 . 3871 . 3871	121. 2 121. 7 122. 2 122. 7 123. 1	5. 725 5. 726 5. 727 5. 728 5. 729	21. 17 21. 25 21. 33 21. 41 21. 49	. 2775 -2 . 2750 -2 . 2725 -2 . 2700 -2 . 2676 -2	$\begin{array}{c ccccc} .7411 & -2 \\ .7382 & -2 \\ .7354 & -2 \\ .7324 & -2 \end{array}$
10. 30 10. 32 10. 34 10. 36 10. 38	.1909 -4 .1885 -4 .1861 -4	. 4258 -3 . 4219 -3 . 4180 -3	. 4484 - 1 . 4468 - 1 . 4451 - 1	10. 27 10. 29 10. 31	.1437 -2 .1424 -2 .1411 -2 .1398 -2 .1385 -2	621. 9 627. 6 633. 4	2. 393731 2. 393940 2. 394147 2. 394354 2. 394559	103. 11 103. 16 103. 21 103. 27 103. 31	5. 571 5. 561 5. 550 5. 539 5. 528	. 3870 . 3870 . 3870 . 3869 . 3869	123. 6 124. 1 124. 6 125. 1 125. 5	5, 730 5, 731 5, 732 5, 733 5, 734	21. 57 21. 65 21. 73 21. 81 21. 89	. 2651 -2 . 2627 -2 . 2603 -2 . 2580 -2 . 2557 -2	.7268 -2 .7240 -2 .7213 -2 .7185 -2
10. 40 10. 42 10. 44 10. 46 10. 48	.1790 .1767 .1745	. 4066 -8 4 . 4029 -8 4 . 3993 -8	. 4402 - . 4386 - . 4370 -	10. 37 10. 39 10. 41	. 1373 -2 . 1361 -2 . 1348 -2 . 1336 -2 . 1324 -2	651. 0 656. 9 662. 9	2. 394763 2. 394966 2. 395167 2. 395368 2. 395568	103. 36 103. 41 103. 47 103. 52 103. 56	5. 518 5. 507 5. 497 5. 486 5. 476	. 3869 . 3868 . 3868 . 3868 . 3867	126. 0 126. 5 127. 0 127. 5 128. 0	5. 735 5. 736 5. 737 5. 738 5. 739	21. 97. 22. 06 22. 14 22. 22 22. 30	. 2534 -2 . 2511 -2 . 2488 -2 . 2466 -2 . 2444 -2	.7130 -2 .7102 -2 .7075 -2

#### TABLE II.—SUPERSONIC FLOW—Continued

							$\gamma = 7/3$	5							
$M$ or $M_1$	$\frac{p}{p_i}$	$\frac{\rho}{\rho \iota}$	$\frac{T}{T_t}$	β	$\frac{q}{p_i}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$\frac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
10. 50	.1701 -4	. 3920 -3	. 4338 -1	10. 45	. 1313 -2	675. 0	2. 395766	103. 61	5. 465	. 3867	128. 5	5. 740	22. 38	$\begin{array}{ccccc} .2422 & -2 \\ .2400 & -2 \\ .2379 & -2 \\ .2358 & -2 \\ .2337 & -2 \end{array}$	. 7022 -2
10. 52	.1679 -4	. 3885 -3	. 4323 -1	10. 47	. 1301 -2	681. 1	2. 395964	103. 66	5. 455	. 3867	129. 0	5. 741	22. 46		. 6996 -2
10. 54	.1658 -4	. 3850 -3	. 4307 -1	10. 49	. 1289 -2	687. 3	2. 396160	103. 71	5. 444	. 3866	129. 4	5. 742	22. 54		. 6968 -2
10. 56	.1637 -4	. 3815 -3	. 4291 -1	10. 51	. 1278 -2	693. 5	2. 396355	103. 76	5. 434	. 3866	129. 9	5. 743	22. 63		. 6942 -2
10. 58	.1616 -4	. 3780 -3	. 4276 -1	10. 53	. 1267 -2	699. 7	2. 396550	103. 81	5. 424	. 3866	130. 4	5. 744	22. 71		. 6917 -2
10. 60	.1596 -4	. 3747 -3	. 4260 -1	10. 55	$\begin{array}{cccc} .1255 & -2 \\ .1244 & -2 \\ .1233 & -2 \\ .1223 & -2 \\ .1212 & -2 \end{array}$	706. 0	2. 396743	103. 86	5. 413	. 3865	130. 9	5. 744	22. 79	. 2317 -2	. 6891 -2
10. 62	.1576 -4	. 3713 -3	. 4245 -1	10. 57		712. 3	2. 396935	103. 90	5. 403	. 3865	131. 4	5. 745	22. 87	. 2296 -2	. 6866 -2
10. 64	.1556 -4	. 3680 -3	. 4230 -1	10. 59		718. 7	2. 397126	103. 96	5. 393	. 3865	131. 9	5. 746	22. 96	. 2276 -2	. 6839 -2
10. 66	.1537 -4	. 3647 -3	. 4215 -1	10. 61		725. 2	2. 397316	104. 01	5. 383	. 3864	132. 4	5. 747	23. 04	. 2256 -2	. 6814 -2
10. 68	.1518 -4	. 3614 -3	. 4200 -1	10. 63		731. 6	2. 397505	104. 05	5. 373	. 3864	132. 9	5. 748	23. 12	. 2236 -2	. 6789 -2
10. 70 10. 72 10. 74 10. 76 10. 78	.1499 -4 .1480 -4 .1462 -4 .1444 -4 .1426 -4	.3582 -3 .3550 -3 .3518 -3 .3487 -3 .3456 -3	. 4185 -1 . 4170 -1 . 4155 -1 . 4140 -1 . 4125 -1	10. 65 10. 67 10. 69 10. 71 10. 73	$\begin{array}{cccc} .1201 & -2 \\ .1191 & -2 \\ .1180 & -2 \\ .1170 & -2 \\ .1160 & -2 \end{array}$	738. 2 744. 8 751. 4 758. 1 764. 8	2. 397693 2. 397880 2. 398066 2. 398251 2. 398435	104. 10 104. 14 104. 19 104. 24 104. 29	5. 363 5. 353 5. 343 5. 333 5. 323	. 3864 . 3863 . 3863 . 3863 . 3862	133. 4 133. 9 134. 4 134. 9 135. 4	5. 749 5. 750 5. 751 5. 752 5. 753	23. 21 23. 29 23. 37 23. 46 23. 54	$\begin{array}{ccccc} .2216 & -2 \\ .2197 & -2 \\ .2178 & -2 \\ .2159 & -2 \\ .2140 & -2 \\ \end{array}$	.6763 -2 .6737 -2 .6712 -2 .6688 -2 .6663 -2
10. 80	.1408 -4	.3426 -3	. 4111 -1	10. 75	.1150 -2	771. 5	2. 398618	104. 33	5. 313	. 3862	135. 9	5. 753	23. 62	. 2121 -2	$\begin{array}{cccc} .6638 & -2 \\ .6614 & -2 \\ .6589 & -2 \\ .6565 & -2 \\ .6542 & -2 \end{array}$
10. 82	.1391 -4	.3395 -3	. 4096 -1	10. 77	.1140 -2	778. 4	2. 398801	104. 38	5. 303	. 3862	136. 4	5. 754	23. 71	. 2103 -2	
10. 84	.1374 -4	.3365 -3	. 4081 -1	10. 79	.1130 -2	785. 2	2. 398982	104. 43	5. 293	. 3862	136. 9	5. 755	23. 79	. 2085 -2	
10. 86	.1357 -4	.3336 -3	. 4067 -1	10. 81	.1120 -2	792. 1	2. 399162	104. 48	5. 283	. 3861	137. 4	5. 756	23. 88	. 2067 -2	
10. 88	.1340 -4	.3306 -3	. 4053 -1	10. 83	.1110 -2	799. 1	2. 399341	104. 52	5. 274	. 3861	137. 9	5. 757	23. 96	. 2048 -2	
10. 90 10. 92 10. 94 10. 96 10. 98	.1324 -4 .1307 -4 .1291 -4 .1276 -4 .1260 -4	.3277 -3 $.3249 -3$ $.3220 -3$ $.3192 -3$ $.3165 -3$	.4038 -I .4024 -I .4010 -I .3996 -I .3982 -I	10. 85 10. 87 10. 89 10. 91 10. 93	.1161 -2 .1091 -2 .1082 -2 .1073 -2 .1064 -2	806. 1 813. 1 820. 3 827. 4 834. 6	2. 399519 2. 399697 2. 399873 2. 400049 2. 400223	104. 57 104. 61 104. 66 104. 71 104. 75	5. 264 5. 254 5. 245 5. 235 5. 225	. 3861 . 3860 . 3860 . 3860 . 3860	138. 5 139. 0 139. 5 140. 0 140. 5	5. 758 5. 759 5. 759 5. 760 5. 761	24. 05 24. 13 24. 21 24. 30 24. 39	. 2031 -2 . 2013 -2 . 1996 -2 . 1979 -2 . 1962 -2	$\begin{array}{cccc} .6518 & -2 \\ .6494 & -2 \\ .6469 & -2 \\ .6447 & -2 \\ .6424 & -2 \end{array}$
11. 00	.1245 -4	.3137 -3	.3968 -1	10. 95	. 1054 -2	841. 9	2. 400397	104. 80	5. 216	. 3859	141. 0	5. 762	24, 47	. 1945 -2	.6400 -2
11. 02	.1230 -4	.3109 -3	.3954 -1	10. 97	. 1045 -2	849. 2	2. 400570	104. 85	5. 206	. 3859	141. 5	5. 763	24, 56	. 1923 -2	.6376 -2
11. 04	.1215 -4	.3083 -3	.3941 -1	11. 00	. 1036 -2	856. 6	2. 400741	104. 89	5. 197	. 3859	142. 0	5. 764	24, 64	. 1912 -2	.6354 -2
11. 06	.1200 -4	.3056 -3	.3927 -1	11. 02	. 1028 -2	864. 0	2. 400912	104. 93	5. 188	. 3858	142. 5	5. 764	24, 73	. 1896 -2	.6330 -2
11. 08	.1186 -4	.3030 -3	.3913 -1	11. 04	. 1019 -2	871. 5	2. 401082	104. 98	5. 178	. 3858	143. 1	5. 765	24, 81	. 1880 -2	.6308 -2
11. 10	.1171 -4	. 3003 -3	.3900 -1	11.06	.1010 -2	879, 0	2. 401252	105. 02	5. 169	. 3858	143. 6	5. 766	24, 90	. 1864 -2	$\begin{array}{cccc} .6286 & -2 \\ .6263 & -2 \\ .6241 & -2 \\ .6218 & -2 \\ .6197 & -2 \\ \end{array}$
11. 12	.1157 -4	. 2978 -3	.3886 -1	11.08	.1002 -2	886, 6	2. 401420	105. 06	5. 159	. 3858	144. 1	5. 767	24, 99	. 1848 -2	
11. 14	.1143 -4	. 2952 -3	.3873 -1	11.10	.9932 -3	894, 2	2. 401587	105. 11	5. 150	. 3857	144. 6	5. 768	25, 08	. 1832 -2	
11. 16	.1130 -4	. 2927 -3	.3860 -1	11.12	.9847 -3	901, 9	2. 401754	105. 16	5. 141	. 3857	145. 1	5. 768	25, 16	. 1817 -2	
11. 18	.1116 -4	. 2902 -3	.3846 -1	11.14	.9765 -3	909, 6	2. 401919	105. 20	5. 132	. 3857	145. 7	5. 769	25, 25	. 1801 -2	
11. 20	.1103 -4	. 2877 -3	.3833 -1	11. 16	.9683 -3	917. 4	2. 402084	105. 24	5. 123	. 3856	146. 2	5. 770	25. 33	.1786 -2	. 6174 -2
11. 22	.1090 -4	. 2852 -3	.3820 -1	11. 18	.9602 -3	925. 2	2. 402248	105. 28	5. 113	. 3856	146. 7	5. 771	25. 42	.1771 -2	. 6152 -2
11. 24	.1077 -4	. 2828 -3	.3807 -1	11. 20	.9521 -3	933. 1	2. 402412	105. 33	5. 104	. 3856	147. 2	5. 772	25. 51	.1756 -2	. 6131 -2
11. 26	.1064 -4	. 2804 -3	.3794 -1	11. 22	.9440 -3	941. 1	2. 402574	105. 37	5. 095	. 3856	147. 8	5. 772	25. 60	.1742 -2	. 6108 -2
11. 28	.1051 -4	. 2780 -3	.3781 -1	11. 24	.9362 -3	949. 1	2. 402735	105. 42	5. 086	. 3855	148. 3	5. 773	25. 69	.1727 -2	. 6087 -2
11. 30	.1039 -4	. 2756 -3	. 3768 -1	11. 26	. 9283 -3	957. 1	2. 402896	105. 46	5. 077	. 3855	148. 8	5. 774	25, 77	.1712 -2	. 6066 -2
11. 32	.1026 -4	. 2733 -3	. 3755 -1	11. 28	. 9206 -3	965. 3	2. 403056	105. 50	5. 068	. 3855	149. 3	5. 775	25, 86	.1698 -2	. 6044 -2
11. 34	.1014 -4	. 2710 -3	. 3743 -1	11. 30	. 9130 -3	973. 5	2. 403215	105. 55	5. 059	. 3855	149. 9	5. 775	25, 95	.1684 -2	. 6023 -2
11. 36	.1002 -4	. 2687 -3	. 3730 -1	11. 32	. 9054 -3	981. 6	2. 403373	105. 59	5. 050	. 3854	150. 4	5. 776	26, 04	.1670 -2	. 6002 -2
11. 38	.9905 -5	. 2664 -3	. 3717 -1	11. 34	. 8979 -3	989. 9	2. 403531	105. 63	5. 041	. 3854	150. 9	5. 777	26, 12	.1656 -2	. 5981 -2
11. 40	. 9788 -5	. 2642 -3	. 3705 -1	11. 36	. 8904 -3	998.3	2. 403687	105. 67	5. 032	.3854	151. 5	5. 778	26. 21	$\begin{array}{cccc} .1642 & -2 \\ .1629 & -2 \\ .1615 & -2 \\ .1602 & -2 \\ .1589 & -2 \\ \end{array}$	. 5959 -2
11. 42	. 9673 -5	. 2620 -3	. 3692 -1	11. 38	. 8830 -3	1007	2. 403843	105. 71	5. 024	.3854	152. 0	5. 779	26. 30		. 5939 -2
11. 44	. 9559 -5	. 2598 -3	. 3680 -1	11. 40	. 8757 -3	1015	2. 403998	105. 75	5. 015	.3853	152. 5	5. 779	26. 39		. 5918 -2
11. 46	. 9447 -5	. 2576 -3	. 3668 -1	11. 42	. 8685 -3	1024	2. 404152	105. 80	5. 006	.3853	153. 1	5. 780	26. 48		. 5897 -2
11. 48	. 9337 -5	. 2554 -3	. 3655 -1	11. 44	. 8613 -3	1032	2. 404306	105. 84	4. 997	.3853	153. 6	5. 781	26. 57		. 5877 -2
11. 50	. 9228 -5	. 2533 -3	. 3643 -1	11. 46	. 8543 -3	1041	2. 404459	105. 88	4. 989	. 3853	154. 1	5. 781	26. 66	$\begin{array}{cccc} .1575 & -2 \\ .1563 & -2 \\ .1550 & -2 \\ .1537 & -2 \\ .1525 & -2 \\ \end{array}$	. 5858 -2
11. 52	. 9120 -5	. 2512 -3	. 3631 -1	11. 48	. 8472 -3	1050	2. 404610	105. 92	4. 980	. 3852	154. 7	5. 782	26. 75		. 5836 -2
11. 54	. 9014 -5	. 2491 -3	. 3619 -1	11. 50	. 8403 -3	1058	2. 404762	105. 97	4. 971	. 3852	155. 2	5. 783	26. 84		. 5816 -2
11. 56	. 8909 -5	. 2470 -3	. 3607 -1	11. 52	. 8334 -3	1067	2. 404912	106. 01	4. 963	. 3852	155. 7	5. 784	26. 93		. 5797 -2
11. 58	. 8806 -5	. 2450 -3	. 3595 -1	11. 54	. 8266 -3	1076	2. 405062	106. 05	4. 954	. 3852	156. 3	5. 784	27. 02		. 5776 -2
11. 60	. 8704 -5	. 2430 -3	. 3583 -1	11. 56	. 8199 -3	1085	2. 405211	106. 09	4. 945	. 3851	156. 8	5. 785	27. 11	. 1512 -2	.5757 -2
11. 62	. 8604 -5	. 2409 -3	. 3571 -1	11. 58	. 8132 -3	1094	2. 405359	106. 13	4. 937	. 3851	157. 4	5. 786	27. 20	. 1500 -2	.5737 -2
11. 64	. 8505 -5	. 2390 -3	. 3559 -1	11. 60	. 8066 -3	1103	2. 405506	106. 17	4. 928	. 3851	157. 9	5. 787	27. 29	. 1488 -2	.5717 -2
11. 66	. 8406 -5	. 2370 -3	. 3547 -1	11. 62	. 8000 -3	1112	2. 405653	106. 21	4. 920	. 3851	158. 5	5. 787	27. 38	. 1475 -2	.5698 -2
11. 68	. 8310 -5	. 2350 -3	. 3536 -1	11. 64	. 7935 -3	1121	2. 405799	106. 25	4. 912	. 3850	159. 0	5. 788	27. 47	. 1464 -2	.5678 -2
11. 70	. 8215 - c	. 2331 -3	. 3524 -1	11. 66	. 7871 -3	1130	2. 405944	106. 29	4. 903	. 3850	159. 5	5, 789	27. 56	. 1452 -2	. 5659 -2
11. 72	. 8120 - 5	. 2312 -3	. 3512 -1	11. 68	. 7808 -3	1140	2. 406089	106. 33	4. 895	. 3850	160. 1	5, 789	27. 65	. 1440 -2	. 5639 -2
11. 74	. 8027 - 5	. 2293 -3	. 3501 -1	11. 70	. 7744 -3	1149	2. 406233	106. 37	4. 886	. 3850	160. 6	5, 790	27. 74	. 1428 -2	. 5620 -2
11. 76	. 7935 - 5	. 2274 -3	. 3489 -1	11. 72	. 7682 -3	1158	2. 406376	106. 41	4. 878	. 3849	161. 2	5, 791	27. 84	. 1417 -2	. 5601 -2
11. 78	. 7845 - 5	. 2256 -3	. 3478 -1	11. 74	. 7620 -3	1168	2. 406518	106. 45	4. 870	. 3849	161. 7	5, 791	27. 93	. 1465 -2	. 5583 -2
11. 80	. 7755 - 5	. 2237 -3	. 3466 -1	11. 76	. 7559 -3	1177	2. 406660	106. 49	4. 861	. 3849	162. 3	5. 792	28. 02	. 1394 -2	. 5564 -2
11. 82	. 7667 - 5	. 2219 -3	. 3455 -1	11. 78	. 7498 -3	1187	2. 406801	106. 53	4. 853	. 3849	162. 8	5. 793	28. 11	. 1383 -2	. 5544 -2
11. 84	. 7580 - 5	. 2201 -3	. 3444 -1	11. 80	. 7438 -3	1197	2. 406942	106. 57	4. 845	. 3848	163. 4	5. 793	28. 20	. 1372 -2	. 5526 -2
11. 86	. 7494 - 5	. 2183 -3	. 3433 -1	11. 82	. 7379 -3	1206	2. 407081	106. 61	4. 837	. 3848	163. 9	5. 794	28. 30	. 1361 -2	. 5508 -2
11. 88	. 7409 - 1	. 2165 -3	. 3422 -1	11. 84	. 7320 -3	1216	2. 407220	106. 65	4. 829	. 3848	164. 5	5. 795	28. 39	. 1350 -2	. 5489 -2
11. 90	. 7325 -5	$\begin{array}{cccc} .2148 & -3 \\ .2131 & -3 \\ .2113 & -3 \\ .2096 & -3 \\ .2079 & -3 \\ \end{array}$	. 3410 -1	11. 86	. 7261 -3	1226	2. 407359	106, 69	4. 820	. 3848	165. 1	5. 795	28. 48	. 1339 -2	. 5471 -2
11. 92	. 7243 -5		. 3399 -1	11. 88	. 7201 -3	1236	2. 407496	106, 73	4. 812	. 3848	165. 6	5. 796	28. 57	. 1328 -2	. 5453 -2
11. 94	. 7161 -5		. 3388 -1	11. 90	. 7146 -3	1246	2. 407633	106, 76	4. 804	. 3847	166. 2	5. 797	28. 67	. 1318 -2	. 5435 -2
11. 96	. 7080 -5		. 3377 -1	11. 92	. 7089 -3	1256	2. 407770	106, 81	4. 796	. 3847	166. 7	5. 797	28. 76	. 1307 -2	. 5416 -2
11. 98	. 7000 -5		. 3367 -1	11. 94	. 7033 -3	1266	2. 407905	106, 84	4. 788	. 3847	167. 3	5. 798	28. 85	. 1297 -2	. 5397 -2
12. 00	. 6922 -5	. 2063 -3	. 3356 -1	11. 96	. 6978 -3	1276	2. 408040	106. 88	4. 780	. 3847	167. 8	5. 799	28, 94	$\begin{array}{cccc} .1287 & -2 \\ .1277 & -2 \\ .1266 & -2 \\ .1256 & -2 \\ .1247 & -2 \\ \end{array}$	. 5380 -2
12. 02	. 6845 -5	. 2046 -3	. 3345 -1	11. 98	. 6922 -3	1287	2. 408175	106. 92	4. 772	. 3846	168. 4	5. 799	29, 04		. 5362 -2
12. 04	. 6768 -5	. 2030 -3	. 3334 -1	12. 00	. 6868 -3	1297	2. 408308	106. 95	4. 764	. 3846	169. 0	5. 800	29, 13		. 5345 -2
12. 06	. 6692 -5	. 2014 -3	. 3324 -1	12. 02	. 6814 -3	1307	2. 408441	106. 99	4. 756	. 3846	169. 5	5. 801	29, 23		. 5327 -2
12. 08	. 6618 -5	. 1998 -3	. 3313 -1	12. 04	. 6760 -3	1318	2. 408574	107. 03	4. 748	. 3846	170. 1	5. 801	29, 32		. 5309 -2
12. 10	. 6544 -5	$\begin{array}{cccc} .1982 & -3 \\ .1966 & -3 \\ .1950 & -3 \\ .1935 & -3 \\ .1920 & -3 \\ \end{array}$	. 3302 -1	12. 06	. 6707 -3	1328	2. 408706	107. 07	4. 741	.3846	170. 7	5. 802	29. 41	. 1237 -2	. 5292 -2
12. 12	. 6472 -5		. 3292 -1	12. 08	. 6655 -3	1339	2. 408837	107. 11	4. 733	.3845	171. 2	5. 803	29. 51	. 1227 -2	. 5275 -2
12. 14	. 6400 -5		. 3281 -1	12. 10	. 6602 -3	1349	2. 408967	107. 14	4. 725	.3845	171. 8	5. 803	29. 60	. 1217 -2	. 5257 -2
12. 16	. 6328 -5		. 3271 -1	12. 12	. 6550 -3	1360	2. 409097	107. 18	4. 717	.3845	172. 3	5. 804	29. 70	. 1208 -2	. 5240 -2
12. 18	. 6259 -5		. 3261 -1	12. 14	. 6500 -3	1371	2. 409226	107. 22	4. 709	.3845	172. 9	£. 804	29. 79	. 1198 -2	. 5223 -2
12. 20 12. 22 12. 24 12. 26 12. 28	.6189 -5 .6122 -5 .6054 -5 .5987 -5 .5922 -5	$\begin{array}{cccc} .1904 & -3 \\ .1889 & -3 \\ .1874 & -3 \\ .1860 & -3 \\ .1845 & -3 \\ \end{array}$	$\begin{array}{cccc} .3250 & -1 \\ .3240 & -1 \\ .3230 & -1 \\ .3219 & -1 \\ .3209 & -1 \\ \end{array}$	12. 16 12. 18 12. 20 12. 22 12. 24	. 6448 -3 . 6399 -3 . 6349 -3 . 6299 -3 . 6251 -3	1382 1393 1404 1415 1426	2. 409355 2. 409483 2. 409611 2. 409738 2. 409864	107. 26 107. 29 107. 33 107. 36 107. 41	4. 702 4. 694 4. 686 4. 679 4. 671	.3844 .3844 .3844 .3844 .3844	173. 5 174. 1 174. 6 175. 2 175. 8	5. 805 5. 806 5. 806 5. 807 5. 807	29. 89 29. 98 30. 08 30. 17 30. 27	. 1189 -2 . 1180 -2 . 1171 -2 . 1161 -2 . 1153 -2	. 5205 -2 . 5189 -2 . 5172 -2 . 5155 -2 . 5138 -2

# TABLE II.—SUPERSONIC FLOW—Continued

$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho \iota}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{\ell_2}}$
12. 30	. 5857 -5	. 1831 -3	.3199 -1	12. 26	. 6202 -3	1437	2. 409989	107. 44	4. 663	. 3843	176. 3	5, 808	30. 36	. 1144 -2	. 5122 -2
12. 32	. 5792 -5	. 1816 -3	.3189 -1	12. 28	. 6154 -3	1448	2. 410115	107. 48	4. 656	. 3843	176. 9	5, 809	30. 46	. 1135 -2	. 5105 -2
12. 34	. 5729 -5	. 1802 -3	.3179 -1	12. 30	. 6107 -3	1460	2. 410239	107. 51	4. 648	. 3843	177. 5	5, 809	30. 55	. 1126 -2	. 5088 -2
12. 36	. 5667 -5	. 1788 -3	.3169 -1	12. 32	. 6060 -3	1471	2. 410363	107. 55	4. 641	. 3843	178. 1	5, 810	30. 65	. 1117 -2	. 5072 -2
12. 38	. 5605 -5	. 1774 -3	.3159 -1	12. 34	. 6013 -3	1482	2. 410486	107. 59	4. 633	. 3843	178. 6	5, 810	30. 75	. 1109 -2	. 5056 -2
12. 40	.5544 -5	.1760 -3	. 3149 -1	12. 36	$\begin{array}{cccc} .5967 & -3 \\ .5921 & -3 \\ .5876 & -3 \\ .5831 & -3 \\ .5786 & -3 \\ \end{array}$	1494	2. 410609	107. 62	4. 626	.3842	179. 2	5. 811	30. 84	.1100 -2	. 5039 -2
12. 42	.5484 -5	.1747 -3	. 3140 -1	12. 38		1506	2. 410731	107. 66	4. 618	.3842	179. 8	5. 812	30. 94	.1092 -2	. 5023 -2
12. 44	.5424 -5	.1733 -3	. 3130 -1	12. 40		1517	2. 410853	107. 69	4. 611	.3842	180. 4	5. 812	31. 04	.1083 -2	. 5007 -2
12. 46	.5365 -5	.1720 -3	. 3120 -1	12. 42		1529	2. 410974	107. 73	4. 603	.3842	181. 0	5. 813	31. 13	.1075 -2	. 4991 -2
12. 48	.5307 -5	.1706 -3	. 3110 -1	12. 44		1541	2. 411094	107. 77	4. 596	.3842	181. 5	5. 813	31. 23	.1067 -2	. 4975 -2
12. 50 12. 52 12. 54 12. 56 12. 58	.5250 -5 .5193 -5 .5137 -5 .5082 -5 .5028 -5	.1693 -3 .1680 -3 .1667 -3 .1654 -3 .1642 -3	.3101 -1 .3091 -1 .3082 -1 .3072 -1 .3063 -1	12, 46 12, 48 12, 50 12, 52 12, 54	. 5742 -3 . 5698 -3 . 5655 -3 . 5612 -3 . 5570 -3	1553 1565 1577 1589 1601	2. 411214 2. 411333 2. 411452 2. 411571 2. 411688	107. 80 107. 84 107. 87 107. 90 107. 94	4. 589 4. 581 4. 574 4. 367 4. 559	.3841 .3841 .3841 .3841	182. 1 182. 7 183. 3 183. 9 184. 5	5. 814 5. 815 5. 815 5. 816 5. 816	31. 33 31. 42 31. 52 31. 62 31. 72	. 1059 -2 . 1051 -2 . 1043 -2 . 1035 -2 . 1027 -2	. 4960 -2 . 4944 -2 . 4927 -2 . 4912 -2 . 4897 -2
12. 60	.4973 -5	.1629 -3	.3053 -1	12. 56	. 5527 -3	1614	2. 411805	107. 98	4. 552	.3840	185. 1	5. 817	31. 81	.1019 -2	.4881 -2
12. 62	.4920 -5	.1617 -3	.3044 -1	12. 58	. 5486 -3	1626	2. 411922	108. 01	4. 545	.3840	185. 6	5. 817	31. 91	.1011 -2	.4865 -2
12. 64	.4868 -5	.1604 -3	.3035 -1	12. 60	. 5444 -3	1639	2. 412038	108. 05	4. 538	.3840	186. 2	5. 818	32. 01	.1004 -2	.4850 -2
12. 66	.4816 -5	.1592 -3	.3025 -1	12. 62	. 5403 -3	1651	2. 412154	108. 08	4. 530	.3840	186. 8	5. 819	32. 11	.9961 -3	.4835 -2
12. 68	.4764 -5	.1580 -3	.3016 -1	12. 64	. 5362 -3	1664	2. 412269	108. 12	4. 523	.3840	187. 4	5. 819	32. 21	.9885 -3	.4820 -2
12. 70	.4714 -5	.1568 -3	.3007 -1	12. 66	. 5322 -3	1676	2. 412383	108. 15	4. 516	.3839	188. 0	5. 820	32, 31	. 9810 -3	. 4805 -2
12. 72	.4663 -5	.1556 -3	.2998 -1	12. 68	. 5282 -3	1689	2. 412497	108. 18	4. 509	.3839	188. 6	5. 820	32, 41	. 9737 -3	. 4790 -2
12. 74	.4614 -5	.1544 -3	.2989 -1	12. 70	. 5242 -3	1702	2. 412611	108. 22	4. 502	.3839	189. 2	5. 821	32, 50	. 9664 -3	. 4775 -2
12. 76	.4565 -5	.1532 -3	.2979 -1	12. 72	. 5203 -3	1715	2. 412723	108. 25	4. 495	.3839	189. 8	5. 821	32, 60	. 9591 -3	. 4760 -2
12. 78	.4517 -5	.1521 -3	.2970 -1	12. 74	. 5164 -3	1728	2. 412836	108. 29	4. 488	.3839	190. 4	5. 822	32, 70	. 9520 -3	. 4745 -2
12, 80	.4469 -5	.1509 -3	. 2961 -1	12. 76	. 5126 -3	1741	2. 412948	108, 32	4. 481	.3839	191. 0	5. 822	32, 80	.9448 -3	.4730 -2
12, 82	.4422 -5	.1498 -3	. 2952 -1	12. 78	. 5087 -3	1754	2. 413059	108, 35	4. 474	.3838	191. 6	5. 823	32, 90	.9378 -3	.4715 -2
12, 84	.4376 -5	.1487 -3	. 2944 -1	12. 80	. 5050 -3	1767	2. 413170	108, 39	4. 467	.3838	192. 2	5. 823	33, 00	.9308 -3	.4701 -2
12, 86	.4329 -5	.1475 -3	. 2935 -1	12. 82	. 5012 -3	1781	2. 413280	108, 42	4. 460	.3838	192. 8	5. 824	33, 10	.9239 -3	.4686 -2
12, 88	.4284 -5	.1464 -3	. 2926 -1	12. 84	. 4975 -3	1794	2. 413390	108, 45	4. 453	.3838	193. 4	5. 825	33, 20	.9170 -3	.4672 -2
12. 90	.4239 -5	. 1453 -3	. 2917 -1	12. 86	. 4938 -3	1807	2. 413500	108. 49	4. 446	. 3838	194. 0	5. 825	33. 30	.9102 -3	.4657 -2
12. 92	.4195 -5	. 1442 -3	. 2908 -1	12. 88	. 4901 -3	1821	2. 413609	108. 52	4. 439	. 3837	194. 6	5. 826	33. 40	.9035 -3	.4643 -2
12. 94	.4151 -5	. 1432 -3	. 2900 -1	12. 90	. 4865 -3	1835	2. 413717	108. 55	4. 432	. 3837	195. 2	5. 826	33. 50	.8968 -3	.4629 -2
12. 96	.4107 -5	. 1421 -3	. 2891 -1	12. 92	. 4829 -3	1848	2. 413825	108. 59	4. 425	. 3837	195. 8	5. 827	33. 60	.8902 -3	.4614 -2
12. 98	.4065 -8	. 1410 -3	. 2882 -1	12. 94	. 4794 -3	1862	2. 413932	108. 62	4. 419	. 3837	196. 4	5. 827	33. 70	.8836 -3	.4600 -2
13. 00	.4023 -5	. 1400 -3	. 2874 -1	12. 96	.4759 -3	1876	2. 414039	108. 65	4. 412	.3837	197. 0	5. 828	33. 81	.8771 -3	.4586 -2
13. 02	.3981 -5	. 1389 -3	. 2865 -1	12. 98	.4723 -3	1890	2. 414146	108. 69	4. 405	.3837	197. 6	5. 828	33. 91	.8706 -3	.4572 -2
13. 04	.3939 -5	. 1379 -3	. 2857 -1	13. 00	.4689 -3	1904	2. 414252	108. 72	4. 398	.3836	198. 2	5. 829	34. 01	.8642 -3	.4559 -3
13. 06	.3898 -5	. 1369 -3	. 2848 -1	13. 02	.4655 -3	1918	2. 414357	108. 75	4. 391	.3836	198. 8	5. 829	34. 11	.8580 -3	.4544 -2
13. 08	.3858 -5	. 1359 -3	. 2840 -1	13. 04	.4620 -3	1933	2. 414462	108. 78	4. 385	.3836	199. 4	5. 830	34. 21	.8517 -3	.4530 -2
13. 10	.3818 -5	. 1349 -3	. 2831 -1	13. 06	. 4586 -3	1947	2. 414567	108. 82	4. 378	.3836	200. 1	5. 830	34. 31	.8453 -3	.4517 -2
13. 12	.3779 -5	. 1339 -3	. 2823 -1	13. 08	. 4553 -3	1961	2. 414671	108. 85	4. 371	.3836	200. 7	5. 831	34. 42	.8392 -3	.4503 -2
13. 14	.3740 -5	. 1329 -3	. 2814 -1	13. 10	. 4520 -3	1976	2. 414775	108. 88	4. 365	.3836	201. 3	5. 831	34. 52	.8331 -2	.4489 -2
13. 16	.3701 -5	. 1319 -3	. 2806 -1	13. 12	. 4487 -3	1990	2. 414878	108. 91	4. 358	.3835	201. 9	5. 832	34. 62	.8271 -3	.4475 -2
13. 18	.3663 -5	. 1309 -3	. 2798 -1	13. 14	. 4454 -3	2005	2. 414981	108. 94	4. 351	.3835	202. 5	5. 832	34. 72	.8210 -3	.4462 -2
13. 20	. 3626 -5	. 1300 -3	. 2790 -1	13. 16	. 4422 -3	2020	2. 415083	108. 97	4. 345	. 3835	203. 1	5, 833	34, 82	.8151 -3	.4448 -2
13. 22	. 3589 -5	. 1290 -3	. 2781 -1	13. 18	. 4390 -3	2034	2. 415185	109. 01	4. 338	. 3835	203. 7	5, 833	34, 93	.8091 -3	.4435 -2
13. 24	. 3552 -5	. 1281 -3	. 2773 -1	13. 20	. 4358 -3	2049	2. 415286	109. 04	4. 332	. 3835	204. 4	5, 834	35, 03	.8032 -3	.4422 -2
13. 26	. 3516 -5	. 1271 -3	. 2765 -1	13. 22	. 4327 -3	2064	2. 415387	109. 07	4. 325	. 3835	205. 0	5, 834	35, 13	.7974 -3	.4409 -2
13. 28	. 3480 -5	. 1262 -3	. 2757 -1	13. 24	. 4296 -3	2079	2. 415488	109. 10	4. 319	. 3834	205. 6	5, 835	35, 24	.7918 -3	.4395 -2
13. 30	.3444 -5	. 1253 -3	. 2749 -1	13, 26	. 4264 -3	2095	2. 415588	109. 13	4, 312	.3834	206. 2	5. 835	35. 34	. 7860 -3	. 4382 -2
13. 32	.3409 -5	. 1244 -3	. 2741 -1	13, 28	. 4234 -3	2110	2. 4156876	109. 16	4, 306	.3834	206. 8	5. 836	35. 44	. 7802 -3	. 4369 -2
13. 34	.3374 -5	. 1235 -3	. 2733 -1	13, 30	. 4203 -3	2125	2. 4157868	109. 20	4, 299	.3834	207. 5	5. 836	35. 55	. 7747 -3	. 4356 -2
13. 36	.3340 -5	. 1226 -3	. 2725 -1	13, 32	. 4173 -3	2141	2. 4158856	109. 23	4, 293	.3834	208. 1	5. 837	35. 65	. 7691 -3	. 4342 -2
13. 38	.3306 -5	. 1217 -3	. 2717 -1	13, 34	. 4143 -3	2156	2. 4159839	109. 26	4, 286	.3834	208. 7	5. 837	35. 76	. 7636 -3	. 4330 -2
13. 40 13. 42 13. 44 13. 46 13. 48	$ \begin{array}{rrrr} .3273 & -5 \\ .3240 & -5 \\ .3207 & -6 \\ .3175 & -5 \\ .3143 & -5 \end{array} $	. 1208 -3 . 1199 -3 . 1191 -3 . 1182 -3 . 1174 -3	$\begin{array}{ccccc} .2709 & ^{-1}\\ .2701 & ^{-1}\\ .2694 & ^{-1}\\ .2686 & ^{-1}\\ .2678 & ^{-1}\\ \end{array}$	13. 36 13. 38 13. 40 13. 42 13. 44	. 4113 -3 . 4084 -3 . 4055 -3 . 4026 -3 . 3997 -3	2172 2188 2204 2219 2236	2. 4160818 2. 4161793 2. 4162763 2. 4163730 2. 4164692	109. 29 109. 32 109. 35 109. 38 109. 41	4. 280 4. 273 4. 267 4. 261 4. 254	.3833 .3833 .3833 .3833 .3833	209. 3 210. 0 210. 6 211. 2 211. 8	5. 838 5. 838 5. 838 5. 839 5. 839	35. 86 35. 96 36. 07 36. 17 36. 28	.7582 -3 .7527 -3 .7474 -3 .7420 -3 .7367 -3	. 4316 -2 . 4304 -2 . 4291 -2 . 4278 -2 . 4265 -2
13. 50 13. 52 13. 54 13. 56 13. 58	$\begin{array}{rrrr} .3111 & -5 \\ .3080 & -5 \\ .3049 & -5 \\ .3019 & -5 \\ .2988 & -5 \end{array}$	. 1165 -3 . 1157 -3 . 1149 -3 . 1140 -3 . 1132 -3	$\begin{array}{ccccc} .2670 & -1 \\ .2663 & -1 \\ .2655 & -1 \\ .2647 & -1 \\ .2640 & -1 \\ \end{array}$	13. 46 13. 48 13. 50 13. 52 13. 54	.3969 -3 .3941 -3 .3913 -3 .3885 -3 .3858 -3	2252 2268 2284 2300 2317	2. 4165650 2. 4166604 2. 4167554 2. 4168499 2. 4169441	109. 44 109. 47 109. 51 109. 54 109. 57	4, 248 4, 242 4, 235 4, 229 4, 223	.3833 .3832 .3832 .3832 .3832	212. 5 213. 1 213. 7 214. 4 215. 0	5. 840 5. 840 5. 841 5. 841 5. 842	36. 38 36. 49 36. 59 36. 70 36. 80	.7315 -3 .7263 -3 .7212 -3 .7161 -3 .7109 -3	. 4253 -2 . 4241 -2 . 4228 -2 . 4216 -2 . 4204 -2
13. 60	. 2958 -5	.1124 -3	. 2632 -1	13. 56	. 3830 -3	2334	2. 4170379	109. 59	4. 217	.3832	215. 6	5. 842	36. 91	.7059 -3	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
13. 62	. 2929 -5	.1116 -3	. 2625 -1	13. 58	. 3803 -3	2350	2. 4171312	109. 62	4. 211	.3832	216. 3	5. 843	37. 02	.7009 -3	
13. 64	. 2900 -5	.1108 -3	. 2617 -1	13. 60	. 3777 -3	2367	2. 4172242	109. 65	4. 204	.3832	216. 9	5. 843	37. 12	.6960 -3	
13. 66	. 2871 -5	.1100 -3	. 2610 -1	13. 62	. 3750 -3	2384	2. 4173167	109. 69	4. 198	.3831	217. 5	5. 843	37. 23	.6911 -3	
13. 68	. 2842 -5	.1092 -3	. 2602 -1	13. 64	. 3724 -3	2401	2. 4174089	109. 72	4. 192	.3831	218. 2	5. 844	37. 33	.6862 -3	
13. 70	. 2814 -5	.1085 -3	. 2595 -1	13. 66	. 3697 -3	2418	2. 4175007	109. 75	4. 186	.3831	218. 8	5. 844	37. 44	.6814 -3	. 4130 -2
13. 72	. 2787 -5	.1077 -3	. 2588 -1	13. 68	. 3672 -3	2435	2. 4175921	109. 77	4. 180	.3831	219. 4	5. 845	37. 55	.6767 -3	. 4118 -2
13. 74	. 2759 -5	.1069 -3	. 2580 -1	13. 70	. 3646 -3	2452	2. 4176831	109. 81	4. 174	.3831	220. 1	5. 845	37. 65	.6719 -3	. 4106 -2
13. 76	. 2732 -5	.1062 -3	. 2573 -1	13. 72	. 3620 -3	2470	2. 4177737	109. 84	4. 168	.3831	220. 7	5. 846	37. 76	.6672 -3	. 4094 -2
13. 78	. 2705 -5	.1054 -3	. 2566 -1	13. 74	. 3595 -3	2487	2. 4178639	109. 86	4. 162	.3831	221. 4	5. 846	37. 87	.6626 -3	. 4082 -2
13.80	. 2678 -5	. 1047 -3	. 2558 -1	13. 76	. 3570 -3	2505	2. 4179537	109. 89	4. 156	. 3830	222. 0	5. 847	37. 97	.6580 -3	. 4070 -2
13.82	. 2652 -5	. 1040 -3	. 2551 -1	13. 78	. 3545 -3	2522	2. 4180432	109. 92	4. 150	. 3830	222. 7	5. 847	38. 08	.6533 -3	. 4059 -2
13.84	. 2626 -5	. 1032 -3	. 2544 -1	13. 80	. 3521 -3	2540	2. 4181323	109. 95	4. 144	. 3830	223. 3	5. 847	38. 19	.6489 -3	. 4047 -2
13.86	. 2600 -5	. 1025 -3	. 2537 -1	13. 82	. 3497 -3	2558	2. 4182210	109. 98	4. 137	. 3830	224. 0	5. 848	38. 30	.6443 -3	. 4036 -2
13.88	. 2575 -5	. 1018 -3	. 2530 -1	13. 84	. 3472 -3	2576	2. 4183093	110. 01	4. 132	. 3830	224. 6	5. 848	38. 41	.6398 -3	. 4024 -2
13. 90	. 2550 -5	.1011 -3	. 2523 -1	13. 86	.3448 -3	2594	2. 4183973	110.04	4. 126	. 3830	225. 3	5. 849	38. 51	.6354 -3	. 4013 -2
13. 92	. 2525 -5	.1004 -3	. 2516 -1	13. 88	.3424 -3	2612	2. 4184849	110.07	4. 120	. 3830	225. 9	5. 849	38. 62	.6310 -3	. 4001 -2
13. 94	. 2500 -5	.9966 -4	. 2509 -1	13. 90	.3401 -3	2630	2. 4185721	110.09	4. 114	. 3829	226. 5	5. 850	38. 73	.6267 -3	. 3989 -2
13. 96	. 2476 -5	.9897 -4	. 2502 -1	13. 92	.3377 -3	2648	2. 4186590	110.12	4. 108	. 3829	227. 2	5. 850	38. 84	.6223 -3	. 3978 -2
13. 98	. 2452 -5	.9828 -4	. 2495 -1	13. 94	.3354 -3	2667	2. 4187455	110.15	4. 102	. 3829	227. 9	5. 850	38. 95	.6180 -3	. 3967 -2
14.00 14.02 14.04 14.06 14.08	. 2428 -5 . 2404 -5 . 2381 -5 . 2358 -5 . 2335 -5		. 2488 -1 . 2481 -1 . 2474 -1 . 2467 -1 . 2460 -1	14.02	. 3331 -3 . 3308 -3 . 3286 -3 . 3263 -3 . 3241 -3	2685 2704 2723 2742 2761	2. 4188316 2. 4189174 2. 4190028 2. 4190879 2. 4191726	110. 18 110. 21 110. 24 110. 26 110. 29	4. 096 4. 090 4. 084 4. 079 4. 073	. 3829 . 3829 . 3829 . 3829 . 3828	228. 5 229. 2 229. 8 230. 5 231. 1	5. 851 5. 851 5. 852 5. 852 5. 852 5. 852	39. 06 39. 16 39. 27 39. 38 39. 49	.6138 -3 .6096 -3 .6054 -3 .6013 -3 .5971 -3	.3956 -2 .3944 -2 .3933 -2 .3922 -2 .3911 -2

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## TABLE II.—SUPERSONIC FLOW—Continued

1	1				1 4		$\gamma = 7/5$		1	1					
$M$ or $M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho \iota}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	V a*	ν	μ	$M_2$	$rac{p_2}{p_1}$	ρ <sub>2</sub> <b>ρ</b> 1	$T_1$	$rac{p_{i_2}}{p_{i_1}}$	$rac{p_1}{p_{t_2}}$
14. 10	. 2313 -5	. 9427 -4	. 2453 -1	14. 06	$\begin{array}{rrrr} .3219 & ^{-3} \\ .3197 & ^{-3} \\ .3175 & ^{-3} \\ .3153 & ^{-3} \\ .3132 & ^{-3} \end{array}$	2780	2. 4192569	110. 32	4. 067	. 3828	231. 8	5. 853	39. 60	.5931 -3	. 3900 -2
14. 12	. 2290 -5	. 9362 -4	. 2447 -1	14. 08		2799	2. 4193409	110. 35	4. 061	. 3828	232. 4	5. 853	39. 71	.5890 -3	. 3889 -2
14. 14	. 2268 -5	. 9297 -4	. 2440 -1	14. 10		2818	2. 4194246	110. 38	4. 055	. 3828	233. 1	5. 854	39. 82	.5849 -3	. 3878 -2
14. 16	. 2246 -5	. 9233 -4	. 2433 -1	14. 13		2838	2. 4195079	110. 41	4. 050	. 3828	233. 8	5. 854	39. 93	.5810 -3	. 3867 -2
14. 18	. 2225 -5	. 9170 -4	. 2426 -1	14. 15		2857	2. 4195909	110. 44	4. 044	. 3828	234. 4	5. 854	40. 04	.5770 -3	. 3856 -2
14. 20	. 2204 -5	. 9108 -4	. 2420 -1	14. 17	.3111 -3	2877	2. 4196735	110. 46	4. 038	. 3828	235. 1	5. 855	40. 15	.5732 -3	.3845 -2
14. 22	. 2183 -5	. 9045 -4	. 2413 -1	14. 19	.3089 -3	2897	2. 4197558	110. 49	4. 033	. 3827	235. 7	5. 855	40. 26	.5693 -3	.3834 -2
14. 24	. 2162 -5	. 8983 -4	. 2406 -1	14. 21	.3068 -3	2916	2. 4198378	110. 52	4. 027	. 3827	236. 4	5. 856	40. 37	.5654 -3	.3824 -2
14. 26	. 2141 -5	. 8922 -4	. 2400 -1	14. 23	.3048 -3	2936	2. 4199194	110. 54	4. 021	. 3827	237. 1	5. 856	40. 48	.5616 -3	.3813 -2
14. 28	. 2121 -5	. 8861 -4	. 2393 -1	14. 25	.3027 -3	2956	2. 4200007	110. 57	4. 016	. 3827	237. 7	5. 856	40. 60	.5578 -3	.3802 -2
14. 30	.2100 -5	.8800 -4	. 2387 -1	14. 27	.3006 -3	2977	2. 4200816	110. 60	4. 010	. 3827	238. 4	5, 857	40. 71	.5540 -3	.3791 -2
14. 32	.2080 -5	.8740 -4	. 2380 -1	14. 29	.2986 -3	2997	2. 4201622	110. 63	4. 004	. 3827	239. 1	5, 857	40. 82	.5503 -3	.3780 -2
14. 34	.2061 -5	.8682 -4	. 2374 -1	14. 31	.2967 -3	3017	2. 4202425	110. 65	3. 999	. 3827	239. 7	5, 858	40. 93	.5466 -3	.3771 -2
14. 36	.2041 -5	.8623 -4	. 2367 -1	14. 33	.2946 -3	3038	2. 4203225	110. 68	3. 993	. 3827	240. 4	5, 858	41. 04	.5429 -3	.3760 -2
14. 38	.2022 -5	.8565 -4	. 2361 -1	14. 35	.2927 -3	3058	2. 4204021	110. 71	3. 988	. 3826	241. 1	5, 858	41. 15	.5393 -3	.3750 -2
14. 40	. 2003 -5	.8506 -4	. 2355 -1	14. 37	. 2907 -3	3079	2. 4204815	110.74	3. 982	. 3826	241. 8	5.859	41. 26	.5357 -3	.3739 -2
14. 42	. 1984 -5	.8449 -4	. 2348 -1	14. 39	. 2888 -3	3100	2. 4205604	110.76	3. 977	. 3826	242. 4	5.859	41. 38	.5321 -3	.3729 -2
14. 44	. 1965 -5	.8392 -4	. 2342 -1	14. 41	. 2869 -3	3121	2. 4206391	110.79	3. 971	. 3826	243. 1	5.860	41. 49	.5285 -3	.3719 -2
14. 46	. 1947 -5	.8335 -4	. 2335 -1	14. 43	. 2849 -3	3142	2. 4207175	110.81	3. 966	. 3826	243. 8	5.860	41. 60	.5250 -3	.3708 -2
14. 48	. 1929 -5	.8280 -4	. 2329 -1	14. 45	. 2830 -3	3163	2. 4207955	110.84	3. 960	. 3826	244. 5	5.860	41. 71	.5215 -3	.3698 -2
14, 50	. 1910 -5	.8224 -4	.2323 -1	14. 47	. 2812 -3	3184	2. 4208732	110. 87	3. 955	. 3826	245. 1	5. 861	41. 83	.5180 -3	.3688 -2 $.3677 -2$ $.3668 -2$ $.3657 -2$ $.3647 -2$
14, 52	. 1892 -5	.8168 -4	.2317 -1	14. 49	. 2793 -3	3206	2. 4209506	110. 90	3. 949	. 3825	245. 8	5. 861	41. 94	.5146 -3	
14, 54	. 1875 -5	.8114 -4	.2310 -1	14. 51	. 2774 -3	3227	2. 4210277	110. 92	3. 944	. 3825	246. 5	5. 861	42. 05	.5111 -3	
14, 56	. 1857 -5	.8059 -4	.2304 -1	14. 53	. 2756 -3	3249	2. 4211045	110. 95	3, 938	. 3825	247. 2	5. 862	42. 17	.5078 -3	
14, 58	. 1840 -5	.8005 -4	.2298 -1	14. 55	. 2737 -3	3271	2. 4211810	110. 97	3. 933	. 3825	247. 8	5. 862	42. 28	.5044 -3	
14. 60 14. 62 14. 64 14. 66 14. 68	$\begin{array}{cccc} .1823 & -5 \\ .1806 & -5 \\ .1789 & -5 \\ .1772 & -5 \\ .1756 & -5 \\ \end{array}$	.7952 -4 .7899 -4 .7847 -4 .7794 -4 .7743 -4	. 2292 -1 . 2286 -1 . 2280 -1 . 2274 -1 . 2268 -1	14. 57 14. 59 14. 61 14. 63 14. 65	. 2720 -3 . 2702 -3 . 2684 -3 . 2666 -3 . 2649 -3	3292 3314 3336 3359 3381	2. 4212572 2. 4213330 2. 4214086 2. 4214838 2. 4215588	111. 00 111. 03 111. 05 111. 08 111. 10	3. 927 3. 922 3. 917 3. 911 3. 906	. 3825 . 3825 . 3825 . 3825 . 3825	248. 5 249. 2 249. 9 250. 6 251. 3	5. 863 5. 863 5. 863 5. 864 5. 864	42. 39 42. 51 42. 62 42. 73 42. 85	.5011 -3 .4978 -3 .4945 -3 .4912 -3 .4880 -3	$\begin{array}{ccccc} .3638 & ^{-2} \\ .3628 & ^{-2} \\ .3618 & ^{-2} \\ .3608 & ^{-2} \\ .3598 & ^{-2} \end{array}$
14. 70 14. 72 14. 74 14. 76 14. 78	$\begin{array}{cccc} .1739 & -5 \\ .1723 & -5 \\ .1707 & -5 \\ .1692 & -5 \\ .1676 & -5 \\ \end{array}$	.7691 -4 .7640 -4 .7590 -4 .7540 -4 .7490 -4	. 2262 -1 . 2256 -1 . 2250 -1 . 2244 -1 . 2238 -1	14. 67 14. 69 14. 71 14. 73 14. 75	. 2631 -3 . 2614 -3 . 2597 -3 . 2580 -3 . 2563 -3	3404 3426 3449 3472 3494	2. 4216335 2. 4217078 2. 4217819 2. 4218557 2. 4219292	111. 13 111. 16 111. 18 111. 21 111. 23	3. 901 3. 895 3. 890 3. 885 3. 880	. 3824 . 3824 . 3824 . 3824 . 3824	251. 9 252. 6 253. 3 254. 0 254. 7	5. 864 5. 865 5. 865 5. 865 5. 866	42. 96 43. 08 43. 19 43. 31 43. 42	.4847 $-3$ $.4816$ $-3$ $.4784$ $-3$ $.4753$ $-3$ $.4722$ $-3$	.3588 -2 .3578 -2 .3569 -2 .3559 -2 .3550 -2
14. 80	$\begin{array}{cccc} .1660 & ^{-5} \\ .1645 & ^{-5} \\ .1630 & ^{-5} \\ .1615 & ^{-5} \\ .1600 & ^{-5} \\ \end{array}$	.7440 -4	. 2232 -1	14. 77	. 2546 -3	3518	2. 4220023	111. 26	3. 874	. 3824	255. 4	5. 866	43. 54	. 4691 -3	. 3540 -2
14. 82		.7392 -4	. 2226 -1	14. 79	. 2530 -3	3541	2. 4220752	111. 28	3. 869	. 3824	256. 1	5. 866	43. 65	. 4660 -3	. 3531 -2
14. 84		.7343 -4	. 2220 -1	14. 81	. 2513 -3	3564	2. 4221479	111. 31	3. 864	. 3824	256. 8	5. 867	43. 77	. 4630 -3	. 3521 -2
14. 86		.7295 -4	. 2214 -1	14. 83	. 2497 -3	3588	2. 4222202	111. 34	3. 859	. 3823	257. 5	5. 867	43. 88	. 4600 -3	. 3512 -2
14. 88		.7247 -4	. 2208 -1	14. 85	. 2480 -3	3611	2. 4222922	111. 36	3. 853	. 3823	258. 2	5. 868	44. 00	. 4570 -3	. 3502 -2
14. 90	.1586 -5	.7199 -4	. 2203 -1	14. 87	. 2464 -3	3635	2. 4223640	111. 38	3. 848	. 3823	258. 9	5. 868	44. 11	. 4540 -3	.3493 -2
14. 92	.1571 -5	.7153 -4	. 2197 -1	14. 89	. 2449 -3	3659	2. 4224355	111. 41	3. 843	. 3823	259. 5	5. 868	44. 23	. 4511 -3	.3483 -2
14. 94	.1557 -5	.7106 -4	. 2191 -1	14. 91	. 2433 -3	3683	2. 4225066	111. 43	3. 838	. 3823	260. 2	5. 869	44. 35	. 4481 -3	.3474 -2
14. 96	.1543 -5	.7059 -4	. 2185 -1	14. 93	. 2417 -3	3707	2. 4225776	111. 46	3. 833	. 3823	260. 9	5. 869	44. 46	. 4452 -3	.3465 -2
14. 98	.1529 -5	.7014 -4	. 2180 -1	14. 95	. 2401 -3	3731	2. 4226482	111. 48	3. 828	. 3823	261. 6	5. 869	44. 58	. 4424 -3	.3456 -2
15. 00	.1515 -5	. 6968 -4	. 2174 -1	14. 97	. 2386 -3	3755	2. 4227186	111. 51	3. 823	. 3823	262. 3	5. 870	44. 69	. 4395 -3	.3446 -2
15. 02	.1501 -5	. 6923 -4	. 2168 -1	14. 99	. 2371 -3	3779	2. 4227886	111. 53	3. 817	. 3823	263. 0	5. 870	44. 81	. 4367 -3	.3437 -2
15. 04	.1487 -5	. 6878 -4	. 2163 -1	15. 01	. 2355 -3	3804	2. 4228585	111. 56	3. 812	. 3822	263. 7	5. 870	44. 93	. 4339 -3	.3428 -2
15. 06	.1474 -5	. 6833 -4	. 2157 -1	15. 03	. 2340 -3	3829	2. 4229280	111. 59	3. 807	. 3822	264. 4	5. 871	45. 05	. 4311 -3	.3419 -2
15. 08	.1461 -5	. 6789 -4	. 2151 -1	15. 05	. 2325 -3	3854	2. 4229973	111. 61	3. 802	. 3822	265. 1	5. 871	45. 16	. 4283 -3	.3410 -2
15. 10 15. 12 15. 14 15. 16 15. 18	$\begin{array}{ccccc} .1447 & -5 \\ .1434 & -5 \\ .1421 & -5 \\ .1409 & -5 \\ .1396 & -5 \\ \end{array}$	. 6745 -4 . 6702 -4 . 6658 -4 . 6615 -4 . 6573 -4	$\begin{array}{ccccc} .2146 & -1 \\ .2140 & -1 \\ .2135 & -1 \\ .2129 & -1 \\ .2124 & -1 \\ \end{array}$	15. 07 15. 09 15. 11 15. 13 15. 15	. 2310 -3 . 2296 -3 . 2281 -3 . 2266 -3 . 2252 -3	3879 3904 3929 3955 3980	2. 4230663 2. 4231350 2. 4232035 2. 4232717 2. 4233396	111. 63 111. 66 111. 68 111. 71 111. 73	3. 797 3. 792 3. 787 3. 782 3. 777	. 3822 . 3822 . 3822 . 3822 . 3822	265. 9 266. 6 267. 3 268. 0 268. 7	5. 871 5. 872 5. 872 5. 872 5. 873	45. 28 45. 40 45. 52 45. 63 45. 75	. 4256 -3 . 4229 -3 . 4201 -3 . 4175 -3 . 4148 -3	.3401 -2 .3392 -2 .3383 -2 .3374 -2 .3365 -2
15. 20 15. 22 15. 24 15. 26 15. 28	$\begin{array}{ccccc} .1383 & ^{-5}\\ .1371 & ^{-5}\\ .1359 & ^{-5}\\ .1347 & ^{-6}\\ .1335 & ^{-3}\\ \end{array}$	. 6531 -4 . 6489 -4 . 6447 -4 . 6406 -4 . 6365 -4	$\begin{array}{ccccc} .2118 & ^{-1}\\ .2113 & ^{-1}\\ .2107 & ^{-1}\\ .2102 & ^{-1}\\ .2097 & ^{-1}\\ \end{array}$	15. 17 15. 19 15. 21 15. 23 15. 25	. 2237 -3 . 2223 -3 . 2209 -3 . 2195 -3 . 2181 -3	4005 4032 4057 4083 4110	2. 4234073 2. 4234747 2. 4235419 2. 4236088 2. 4236754	111. 76 111. 78 111. 80 111. 83 111. 85	3. 772 3. 767 3. 762 3. 757 3. 752	. 3822 . 3821 . 3821 . 3821 . 3821	269. 4 270. 1 270. 8 271. 5 272. 2	5. 873 5. 873 5. 874 5. 874 5. 874	45. 87 45. 99 46. 11 46. 22 46. 34	. 4122 -3 . 4096 -3 . 4070 -3 . 4044 -3 . 4018 -3	.3357 $-2$ $.3347$ $-2$ $.3339$ $-2$ $.3330$ $-2$ $.3321$ $-2$
15. 30 15. 32 15. 34 15. 36 15. 38	.1323 -5 .1311 -5 .1299 -5 .1288 -5 .1276 -5	. 6325 -4 . 6284 -4 . 6244 -4 . 6204 -4 . 6165 -4	. 2091 -1 . 2086 -1 . 2081 -1 . 2075 -1 . 2070 -1	15. 27 15. 29 15. 31 15. 33 15. 35	$\begin{array}{c} .2167 & ^{-3} \\ .2154 & ^{-3} \\ .2140 & ^{-3} \\ .2127 & ^{-3} \\ .2113 & ^{-3} \end{array}$	4135 4162 4189 4215 4242	2. 4237418 2. 4238079 2. 4238738 2. 4239394 2. 4240048	111. 88 111. 90 111. 92 111. 95 111. 97	3. 748 3. 743 3. 738 3. 733 3. 728	. 3821 . 3821 . 3821 . 3821 . 3821	272. 9 273. 7 274. 4 275. 1 275. 8	5. 875 5. 875 5. 875 5. 876 5. 876	46. 46 46. 58 46. 70 46. 82 46. 94	.3992 -3 .3967 -3 .3942 -3 .3917 -3 .3893 -3	$\begin{array}{ccccc} .3313 & -2 \\ .3304 & -2 \\ .3295 & -2 \\ .3287 & -2 \\ .3278 & -2 \\ \end{array}$
15. 40	.1265 -5	. 6126 -4	. 2065 -1	15. 37	. 2100 -3	4269	2. 4240699	112. 00	3. 723	. 3820	276. 5	5. 876	47. 06	.3868 -3	.3270 -2 $.3262 -2$ $.3253 -2$ $.3245 -2$ $.3236 -2$
15. 42	.1254 -5	. 6087 -4	. 2060 -1	15. 39	. 2087 -3	4296	2. 4241348	112. 02	3. 718	. 3820	277. 2	5. 876	47. 18	.3844 -3	
15. 44	.1243 -5	. 6049 -4	. 2054 -1	15. 41	. 2074 -3	4323	2. 4241994	112. 04	3. 714	. 3820	278. 0	5. 877	47. 30	.3820 -3	
15. 46	.1232 -5	. 6010 -4	. 2049 -1	15. 43	. 2061 -3	4351	2. 4242638	112. 06	3. 709	. 3820	278. 7	5. 877	47. 42	.3796 -3	
15. 48	.1221 -8	. 5972 -4	. 2044 -1	15. 45	. 2048 -3	4378	2. 4243280	112. 09	3. 704	. 3820	279. 4	5. 877	47. 54	.3772 -3	
15. 50	.1210 -5	. 5935 -4	. 2039 -1	15. 47	. 2035 -3	4406	2. 4243918	112. 11	3. 699	. 3820	280. 1	5. 878	47. 66	.3748 -3	$\begin{array}{ccccc} .3228 & -2 \\ .3220 & -2 \\ .3211 & -2 \\ .3203 & -2 \\ .3195 & -2 \\ \end{array}$
15. 52	.1199 -5	. 5897 -4	. 2034 -1	15. 49	. 2022 -3	4434	2. 4244555	112. 14	3. 694	. 3820	280. 9	5. 878	47. 78	.3725 -3	
15. 54	.1189 -5	. 5861 -4	. 2029 -1	15. 51	. 2010 -3	4462	2. 4245189	112. 16	3. 690	. 3820	281. 6	5. 878	47. 90	.3702 -3	
15. 56	.1178 -5	. 5824 -4	. 2023 -1	15. 53	. 1997 -3	4490	2. 4245821	112. 18	3. 685	. 3820	282. 3	5. 879	48. 02	.3679 -3	
15. 58	.1168 -5	. 5787 -4	. 2018 -1	15. 55	. 1985 -3	4518	2. 4246450	112. 20	3. 680	. 3819	283. 0	5. 879	48. 14	.3656 -3	
15. 60	.1158 -5	. 5751 -4	$\begin{array}{ccccc} .\ 2013 & ^{-1}\\ .\ 2008 & ^{-1}\\ .\ 2003 & ^{-1}\\ .\ 1998 & ^{-1}\\ .\ 1993 & ^{-1}\\ \end{array}$	15. 57	.1972 -3	4546	2. 4247077	112. 23	3. 675	. 3819	283. 8	5. 879	48. 26	.3633 -3	. 3187 -2
15. 62	.1148 -5	. 5715 -4		15. 59	.1960 -3	4575	2. 4247702	112. 25	3. 671	. 3819	284. 5	5. 880	48. 39	.3610 -3	. 3179 -2
15. 64	.1138 -5	. 5679 -4		15. 61	.1948 -3	4604	2. 4248324	112. 27	3. 666	. 3819	285. 2	5. 880	48. 51	.3588 -3	. 3170 -2
15. 66	.1128 -5	. 5643 -4		15. 63	.1936 -3	4633	2. 4248944	112. 30	3. 661	. 3819	285. 9	5. 880	48. 63	.3566 -3	. 3162 -2
15. 68	.1118 -5	. 5608 -4		15. 65	.1924 -3	4662	2. 4249562	112. 32	3. 657	. 3819	286. 7	5. 880	48. 75	.3544 -3	. 3154 -2
15. 70	.1108 -5	. 5574 -4	. 1988 -1	15. 67	.1912 -3	4690	2. 4250177	112. 34	3. 652	. 3819	287. 4	5. 881	48. 87	.3522 -3	. 3147 -2
15. 72	.1099 -5	. 5539 -4	. 1983 -1	15. 69	.1900 -3	4720	2. 4250790	112. 37	3. 647	. 3819	288. 1	5. 881	49. 00	.3500 -3	. 3139 -2
15. 74	.1089 -5	. 5505 -4	. 1978 -1	15. 71	.1889 -3	4749	2. 4251401	112. 39	3. 643	. 3819	288. 9	5. 881	49. 12	.3479 -3	. 3131 -2
15. 76	.1079 -5	. 5470 -4	. 1973 -1	15. 73	.1877 -3	4779	2. 4252009	112. 41	3. 638	. 3819	289. 6	5. 882	49. 24	.3457 -3	. 3122 -2
15. 78	.1070 -5	. 5436 -4	. 1968 -1	15. 75	.1865 -3	4809	2. 4252616	112. 43	3. 633	. 3818	290. 3	5. 882	49. 36	.3436 -3	. 3114 -2
15. 80	$ \begin{array}{ccccc} .1061 & -5 \\ .1052 & -5 \\ .1043 & -5 \\ .1034 & -5 \\ .1025 & -6 \end{array} $	. 5403 -4	. 1964 -1	15. 77	.1854 -3	4838	2. 4253220	112. 45	3. 629	.3818	291. 1	5. 882	49. 49	. 3415 -3	. 3107 -2
15. 82		. 5369 -4	. 1959 -1	15. 79	.1843 -3	4868	2. 4253821	112. 48	3. 624	.3818	291. 8	5. 883	49. 61	. 3394 -3	. 3099 -2
15. 84		. 5336 -4	. 1954 -1	15. 81	.1831 -3	4899	2. 4254421	112. 50	3. 620	.3818	292. 6	5. 883	49. 73	. 3373 -3	. 3091 -2
15. 86		. 5303 -4	. 1949 -1	15. 83	.1820 -3	4929	2. 4255018	112. 52	3. 615	.3818	293. 3	5. 883	49. 86	. 3352 -3	. 3083 -2
15. 88		. 5271 -4	. 1944 -1	15. 85	.1809 -3	4959	2. 4255613	112. 55	3. 610	.3818	294. 0	5. 883	49. 98	. 3332 -8	. 3076 -2

### TABLE II.—SUPERSONIC FLOW—Continued

							1								
$M$ or $M_1$	$\frac{p}{p_i}$	$\frac{\rho}{\rho_l}$	$\frac{T}{T_t}$	β	$\frac{q}{p_i}$	$\frac{A}{A_{*}}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
15. 90	.1016 -5	.5238 -4	$\begin{array}{ccccc} .1939 & ^{-1}\\ .1935 & ^{-1}\\ .1930 & ^{-1}\\ .1925 & ^{-1}\\ .1920 & ^{-1}\\ \end{array}$	15. 87	.1798 -3	4990	2. 4256206	112. 57	3. 606	. 3818	294. 8	5. 884	50. 10	. 3311 -3	. 3068 -2
15. 92	.1007 -5	.5206 -4		15. 89	.1787 -3	5020	2. 4256797	112. 59	3. 601	. 3818	295. 5	5. 884	50. 23	. 3291 -3	. 3060 -2
15. 94	.9986 -6	.5174 -4		15. 91	.1776 -3	5051	2. 4257385	112. 61	3. 597	. 3818	296. 3	5. 884	50. 35	. 3271 -3	. 3053 -2
15. 96	.9899 -6	.5142 -4		15. 93	.1765 -3	5082	2. 4257971	112. 63	3. 592	. 3818	297. 0	5. 885	50. 47	. 3251 -3	. 3045 -2
15. 98	.9815 -6	.5111 -4		15. 95	.1754 -3	5113	2. 4258555	112. 66	3. 588	. 3818	297. 8	5. 885	50. 60	. 3232 -3	. 3037 -2
16. 00	. 9731 -6	.5079 -4	.1916 -1	15. 97	.1744 -3	5145	2. 4259137	112. 68	3. 583	. 3817	298. 5	5. 885	50. 72	.3212 -3	$\begin{array}{ccccc} .3030 & -2 \\ .3022 & -2 \\ .3015 & -2 \\ .3007 & -2 \\ .3000 & -2 \end{array}$
16. 02	. 9647 -6	.5048 -4	.1911 -1	15. 99	.1733 -3	5176	2. 4259717	112. 70	3. 579	. 3817	299. 3	5. 885	50. 85	.3192 -3	
16. 04	. 9565 -6	.5017 -4	.1906 -1	16. 01	.1723 -3	5208	2. 4260295	112. 72	3. 574	. 3817	300. 0	5. 886	50. 97	.3173 -3	
16. 06	. 9484 -6	.4987 -4	.1902 -1	16. 03	.1712 -3	5239	2. 4260871	112. 74	3. 570	. 3817	300. 7	5. 886	51. 10	.3154 -3	
16. 08	. 9404 -6	.4957 -4	.1897 -1	16. 05	.1702 -3	5271	2. 4261444	112. 76	3. 566	. 3817	301. 5	5. 886	51. 22	.3135 -3	
16. 10 16. 12 16. 14 16. 16 16. 18	. 9323 -6 . 9244 -6 . 9165 -6 . 9089 -6 . 9011 -6	. 4926 -4 . 4897 -4 . 4867 -4 . 4838 -4 . 4808 -4	.1892 -1 .1888 -1 .1883 -1 .1879 -1 .1874 -1	16. 07 16. 09 16. 11 16. 13 16. 15	$\begin{array}{cccc} .1692 & ^{-3} \\ .1681 & ^{-3} \\ .1671 & ^{-3} \\ .1661 & ^{-3} \\ .1651 & ^{-3} \end{array}$	5304 5336 5369 5401 5434	2. 4262015 2. 4262585 2. 4263152 2. 4263717 2. 4264280	112. 79 112. 81 112. 83 112. 85 112. 87	3. 561 3. 557 3. 552 3. 548 3. 543	. 3817 . 3817 . 3817 . 3817 . 3817	302. 3 303. 0 303. 8 304. 5 305. 3	5. 887 5. 887 5. 887 5. 887 5. 888	51. 35 51. 47 51. 60 51. 72 51. 85	.3116 -3 .3097 -3 .3079 -3 .3060 -3 .3042 -3	$\begin{array}{ccccc} .\ 2992 & -2 \\ .\ 2985 & -2 \\ .\ 2977 & -2 \\ .\ 2970 & -2 \\ .\ 2963 & -2 \end{array}$
16. 20 16. 22 16. 24 16. 26 16. 28	.8936 -6 .8860 -6 .8784 -6 .8712 -6 .8638 -6	.4779 -4 .4751 -4 .4721 -4 .4694 -4 .4665 -4	. 1870 -1 . 1865 -1 . 1861 -1 . 1856 -1 . 1852 -1	16. 17 16. 19 16. 21 16. 23 16. 25	$\begin{array}{cccc} .1642 & ^{-3}\\ .1632 & ^{-3}\\ .1622 & ^{-3}\\ .1612 & ^{-3}\\ .1603 & ^{-3}\\ \end{array}$	5466 5499 5533 5566 5600	2. 4264841 2. 4265400 2. 4265958 2. 4266513 2. 4267066	112. 89 112. 91 112. 94 112. 96 112. 98	3. 539 3. 535 3. 530 3. 526 3. 522	. 3817 . 3816 . 3816 . 3816 . 3816	306. 0 306. 8 307. 5 308. 3 309. 0	5. 888 5. 888 5. 888 5. 889 5. 889	51. 97 52. 10 52. 23 52. 35 52. 48	.3024 -3 .3005 -3 .2987 -3 .2969 -3 .2952 -3	$\begin{array}{ccccc} .2955 & -2 \\ .2948 & -2 \\ .2941 & -2 \\ .2934 & -2 \\ .2926 & -2 \end{array}$
16, 30	.8565 -6	. 4637 -4	. 1847 -1	16. 27	.1593 -3	5634	2, 4267617	113. 00	3. 517	. 3816	309. 8	5, 889	52. 61	. 2934 -3	. 2919 -2
16, 32	.8494 -6	. 4609 -4	. 1843 -1	16. 29	.1584 -3	5667	2, 4268166	113. 02	3. 513	. 3816	310. 6	5, 889	52. 73	. 2916 -3	. 2912 -2
16, 34	.8423 -6	. 4582 -4	. 1838 -1	16. 31	.1574 -3	5701	2, 4268713	113. 04	3. 509	. 3816	311. 3	5, 890	52. 86	. 2899 -3	. 2905 -2
16, 36	.8352 -6	. 4554 -4	. 1834 -1	16. 33	.1565 -3	5735	2, 4269258	113. 06	3. 504	. 3816	312. 1	5, 890	52. 99	. 2882 -3	. 2898 -2
16, 38	.8283 -6	. 4527 -4	. 1830 -1	16. 35	.1556 -3	5770	2, 4269801	113. 08	3. 500	. 3816	312. 9	5, 890	53. 12	. 2865 -3	. 2891 -2
16. 40	. 8213 -6	.4500 -4	.1825 -1	16. 37	.1546 -3	5804	2. 4270342	113. 11	3. 496	. 3816	313. 6	5. 891	53. 24	. 2848 -3	. 2884 -2
16. 42	. 8144 -6	.4473 -4	.1821 -1	16. 39	.1537 -3	5839	2. 4270881	113. 13	3. 492	. 3816	314. 4	5. 891	53. 37	. 2831 -3	. 2877 -2
16. 44	. 8077 -6	.4447 -4	.1816 -1	16. 41	.1528 -3	5874	2. 4271418	113. 15	3. 487	. 3815	315. 2	5. 891	53. 50	. 2814 -3	. 2870 -2
16. 46	. 8009 -6	.4420 -4	.1812 -1	16. 43	.1519 -3	5910	2. 4271954	113. 17	3. 483	. 3815	315. 9	5. 891	53. 63	. 2798 -3	. 2863 -2
16. 48	. 7942 -6	.4394 -4	.1808 -1	16. 45	.1510 -3	5945	2. 4272487	113. 19	3. 479	. 3815	316. 7	5. 892	53. 75	. 2781 -3	. 2856 -2
16. 50	$\begin{array}{cccc} .7876 & ^{-6} \\ .7811 & ^{-6} \\ .7747 & ^{-6} \\ .7682 & ^{-6} \\ .7620 & ^{-6} \end{array}$	. 4367 -4	.1803 -1	16. 47	.1501 -3	5980	2. 4273019	113. 21	3. 475	. 3815	317. 5	5. 892	53. 88	.2765 -3	. 2849 -2
16. 52		. 4341 -4	.1799 -1	16. 49	.1492 -3	6016	2. 4273548	113. 23	3. 470	. 3815	318. 2	5. 892	54. 01	.2749 -3	. 2842 -2
16. 54		. 4316 -4	.1795 -1	16. 51	.1484 -3	6051	2. 4274076	113. 25	3. 466	. 3815	319. 0	5. 892	54. 14	.2732 -3	. 2836 -2
16. 56		. 4290 -4	.1791 -1	16. 53	.1475 -3	6087	2. 4274602	113. 27	3. 462	. 3815	319. 8	5. 893	54. 27	.2716 -3	. 2828 -2
16. 58		. 4265 -4	.1786 -1	16. 55	.1466 -3	6123	2. 4275126	113. 29	3. 458	. 3815	320. 6	5. 893	54. 40	.2700 -3	. 2822 -2
16. 60	.7556 -6	. 4240 -4	.1782 -1	16. 57	.1457 -3	6160	2. 4275648	113. 31	3. 454	. 3815	321. 3	5. 893	54. 53	.2685 -3	. 2814 -2
16. 62	.7493 -6	. 4215 -4	.1778 -1	16. 59	.1449 -3	6196	2. 4276169	113. 33	3. 449	. 3815	322. 1	5. 893	54. 66	.2669 -3	. 2808 -2
16. 64	.7432 -6	. 4190 -4	.1774 -1	16. 61	.1440 -3	6233	2. 4276687	113. 35	3. 445	. 3815	322. 9	5. 894	54. 78	.2653 -3	. 2801 -2
16. 66	.7372 -6	. 4166 -4	.1770 -1	16. 63	.1432 -3	6268	2. 4277204	113. 37	3. 441	. 3815	323. 7	5. 894	54. 91	.2638 -3	. 2795 -2
16. 68	.7311 -6	. 4141 -4	.1765 -1	16. 65	.1424 -3	6306	2. 4277719	113. 39	3. 437	. 3814	324. 4	5. 894	55. 04	.2622 -3	. 2788 -2
16. 70 16. 72 16. 74 16. 76 16. 78	$\begin{array}{cccc} .7250 & ^{-6} \\ .7191 & ^{-6} \\ .7132 & ^{-6} \\ .7074 & ^{-6} \\ .7016 & ^{-6} \end{array}$	. 4117 -4 . 4093 -4 . 4069 -4 . 4045 -4 . 4021 -4	.1761 -1 .1757 -1 .1753 -1 .1749 -1 .1745 -1	16. 67 16. 69 16. 71 16. 73 16. 75	.1415 -3 .1407 -3 .1399 -3 .1391 -3 .1383 -3	6343 6380 6417 6455 6493	2. 4278232 2. 4278743 2. 4279252 2. 4279760 2. 4280266	113. 41 113. 43 113. 45 113. 47 113. 49	3. 433 3. 429 3. 425 3. 421 3. 417	.3814 .3814 .3814 .3814 .3814	325. 2 326. 0 326. 8 327. 6 328. 3	5. 894 5. 895 5. 895 5. 895 5. 895	55. 17 55. 30 55. 43 55. 56 55. 69	.2607 -3 .2592 -3 .2577 -3 .2562 -3 .2547 -3	$\begin{array}{cccc} .2781 & -2 \\ .2774 & -2 \\ .2768 & -2 \\ .2762 & -2 \\ .2755 & -2 \end{array}$
16. 80	. 6959 -6	. 3998 -4	.1741 -1	16. 77	.1375 -3	6531	2. 4280770	113. 51	3. 413	. 3814	329. 1	5. 896	55, 82	.2532 -3	$\begin{array}{ccccc} .2748 & -2 \\ .2742 & -2 \\ .2735 & -2 \\ .2729 & -2 \\ .2722 & -2 \end{array}$
16. 82	. 6902 -6	. 3974 -4	.1737 -1	16. 79	.1367 -3	6570	2. 4281272	113. 53	3. 408	. 3814	329. 9	5. 896	55, 96	.2517 -3	
16. 84	. 6846 -6	. 3951 -4	.1733 -1	16. 81	.1359 -3	6607	2. 4281772	113. 55	3. 404	. 3814	330. 7	5. 896	56, 09	.2503 -3	
16. 86	. 6790 -6	. 3928 -4	.1729 -1	16. 83	.1351 -3	6647	2. 4282271	113. 57	3. 400	. 3814	331. 5	5. 896	56, 22	.2488 -3	
16. 88	. 6735 -6	. 3905 -4	.1725 -1	16. 85	.1343 -3	6685	2. 4282768	113. 59	3. 396	. 3814	332. 3	5. 897	56, 35	.2474 -3	
16. 90	. 6680 -6	. 3883 -4	.1721 -1	16. 87	.1336 -3	6724	2. 4283264	113. 61	3. 392	. 3814	333. 1	5. 897	56. 48	. 2460 -3	$\begin{array}{cccc} .2716 & -2 \\ .2709 & -2 \\ .2703 & -2 \\ .2697 & -2 \\ .2690 & -2 \\ \end{array}$
16. 92	. 6626 -6	. 3860 -4	.1717 -1	16. 89	.1328 -3	6763	2. 4283757	113. 63	3. 388	. 3813	333. 8	5. 897	56. 61	. 2446 -3	
16. 94	. 6572 -6	. 3838 -4	.1713 -1	16. 91	.1320 -3	6802	2. 4284249	113. 65	3. 384	. 3813	334. 6	5. 897	56. 74	. 2432 -3	
16. 96	. 6520 -6	. 3816 -4	.1709 -1	16. 93	.1313 -3	6841	2. 4284739	113. 67	3. 380	. 3813	335. 4	5. 898	56. 88	. 2418 -3	
16. 98	. 6467 -6	. 3794 -4	.1705 -1	16. 95	.1305 -3	6881	2. 4285228	113. 69	3. 376	. 3813	336. 2	5. 898	57. 01	. 2404 -3	
17. 00	. 6415 -6	.3772 -4	.1701 -1	16. 97	.1298 -3	6920	2. 4285714	113. 71	3. 372	. 3813	337. 0	5. 898	57. 14	. 2390 -3	. 2684 -2
17. 02	. 6364 -6	.3750 -4	.1697 -1	16. 99	.1290 -3	6960	2. 4286199	113. 73	3. 368	. 3813	337. 8	5. 898	57. 27	. 2376 -3	. 2678 -2
17. 04	. 6311 -6	.3728 -4	.1693 -1	17. 01	.1283 -3	7001	2. 4286683	113. 75	3. 364	. 3813	338. 6	5. 898	57. 40	. 2363 -3	. 2671 -2
17. 06	. 6261 -6	.3707 -4	.1689 -1	17. 03	.1276 -3	7042	2. 4287164	113. 77	3. 360	. 3813	339. 4	5. 899	57. 54	. 2349 -3	. 2665 -2
17. 08	. 6211 -6	.3686 -4	.1685 -1	17. 05	.1268 -3	7081	2. 4287645	113. 79	3. 356	. 3813	340. 2	5. 899	57. 67	. 2336 -3	. 2659 -2
17. 10 17. 12 17. 14 17. 16 17. 18	. 6161 -6 . 6111 -6 . 6063 -6 . 6014 -6 . 5966 -6	. 3665 -4 . 3644 -4 . 3623 -4 . 3602 -4 . 3581 -4	.1681 -1 .1677 -1 .1674 -1 .1670 -1 .1666 -1	17. 07 17. 09 17. 11 17. 13 17. 15	$\begin{array}{c} .1261 & ^{-3} \\ .1254 & ^{-3} \\ .1247 & ^{-3} \\ .1240 & ^{-3} \\ .1233 & ^{-3} \\ \end{array}$	7122 7163 7204 7246 7287	2. 4288123 2. 4288600 2. 4289075 2. 4289548 2. 4290020	113. 81 113. 83 113. 85 113. 87 113. 88	3. 353 3. 349 3. 345 3. 341 3. 337	. 3813 . 3813 . 3813 . 3813 . 3812	341. 0 341. 8 342. 6 343. 4 344. 2	5. 899 5. 899 5. 900 5. 900 5. 900	57. 80 57. 94 58. 07 58. 20 58. 34	. 2322 -3 . 2309 -3 . 2296 -3 . 2283 -3 . 2270 -3	$\begin{array}{ccccc} .2653 & -2 \\ .2646 & -2 \\ .2641 & -2 \\ .2634 & -2 \\ .2628 & -2 \\ \end{array}$
17. 20	. 5918 -6	.3561 -4	.1662 -1	17. 17	.1226 -3	7329	2. 4290490	113, 90	3. 333	. 3812	345. 0	5. 900	58. 47	. 2257 -3	.2622 -2
17. 22	. 5871 -6	.3541 -4	.1658 -1	17. 19	.1219 -3	7371	2. 4290959	113, 92	3. 329	. 3812	345. 8	5. 901	58. 60	. 2245 -3	.2616 -2
17. 24	. 5824 -6	.3520 -4	.1654 -1	17. 21	.1212 -3	7413	2. 4291426	113, 94	3. 325	. 3812	346. 6	5. 901	58. 74	. 2232 -3	.2610 -2
17. 26	. 5779 -6	.3501 -4	.1651 -1	17. 23	.1205 -3	7454	2. 4291891	113, 96	3. 321	. 3812	347. 4	5. 901	58. 87	. 2219 -3	.2604 -2
17. 28	. 5732 -6	.3481 -4	.1647 -1	17. 25	.1198 -3	7497	2. 4292355	113, 98	3. 318	. 3812	348. 2	5. 901	59. 01	. 2207 -3	.2598 -2
17. 30	. 5687 -6	. 3461 -4	.1643 -1	17. 27	.1192 -3	7539	2. 4292818	114. 00	3. 314	. 3812	349. 0	5. 901	59. 14	. 2194 -3	. 2592 -2
17. 32	. 5642 -6	. 3441 -4	.1639 -1	17. 29	.1185 -3	7583	2. 4293278	114. 01	3. 310	. 3812	349. 8	5. 902	59. 27	. 2182 -3	. 2586 -2
17. 34	. 5597 -6	. 3422 -4	.1636 -1	17. 31	.1178 -3	7626	2. 4293737	114. 03	3. 306	. 3812	350. 6	5. 902	59. 41	. 2170 -3	. 2580 -2
17. 36	. 5553 -6	. 3403 -4	.1632 -1	17. 33	.1171 -3	7669	2. 4294195	114. 05	3. 302	. 3812	351. 4	5. 902	59. 54	. 2157 -3	. 2574 -2
17. 38	. 5509 -6	. 3383 -4	.1628 -1	17. 35	.1165 -3	7713	2. 4294651	114. 07	3. 299	. 3812	352. 2	5. 902	59. 68	. 2145 -3	. 2568 -2
17. 40	. 5465 -6	. 3364 -4	.1625 -1	17. 37	.1158 -3	7757	2. 4295105	114. 09	3. 295	. 3812	353. 1	5. 903	59. 81	. 2133 -3	$\begin{array}{ccccc} .2562 & -2 \\ .2557 & -2 \\ .2550 & -2 \\ .2545 & -2 \\ .2539 & -2 \\ \end{array}$
17. 42	. 5423 -6	. 3346 -4	.1621 -1	17. 39	.1152 -3	7799	2. 4295558	114. 11	3. 291	. 3812	353. 9	5. 903	59. 95	. 2121 -3	
17. 44	. 5380 -6	. 3326 -4	.1617 -1	17. 41	.1145 -3	7844	2. 4296010	114. 13	3. 287	. 3811	354. 7	5. 903	60. 09	. 2109 -3	
17. 46	. 5338 -6	. 3308 -4	.1614 -1	17. 43	.1139 -3	7888	2. 4296460	114. 15	3. 283	. 3811	355. 5	5. 903	60. 22	. 2098 -3	
17. 48	. 5295 -6	. 3289 -4	.1610 -1	17. 45	.1133 -3	7933	2. 4296908	114. 16	3. 280	. 3811	356. 3	5. 903	60. 36	. 2086 -3	
17. 50	.5254 -6	.3271 -4	.1606 -1	17. 47	.1126 -3	7977	2. 4297355	114. 18	3. 276	. 3811	357. 1	5. 904	60. 49	. 2074 -3	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
17. 52	.5213 -6	.3252 -4	.1603 -1	17. 49	.1120 -3	8022	2. 4297800	114. 20	3, 272	. 3811	357. 9	5. 904	60. 63	. 2063 -3	
17. 54	.5172 -6	.3234 -4	.1599 -1	17. 51	.1114 -3	8067	2. 4298244	114. 22	3. 268	. 3811	358. 8	5. 904	60. 77	. 2051 -3	
17. 56	.5131 -6	.3216 -4	.1596 -1	17. 53	.1108 -3	8113	2, 4298686	114. 24	3. 265	. 3811	359. 6	5. 904	60. 90	. 2040 -3	
17. 58	.5092 -6	.3198 -4	.1592 -1	17. 55	.1102 -3	8157	2. 4299127	114. 26	3. 261	. 3811	360. 4	5. 905	61. 04	. 2029 -3	
17. 60	.5052 -6	.3180 -4	. 1589 -1	17. 57	.1095 -3	8203	2. 4299566	114. 27	3. 257	. 3811	361. 2	5. 905	61. 18	. 2017 -3	$\begin{array}{ccccc} .2504 & -2 \\ .2499 & -2 \\ .2493 & -2 \\ .2488 & -2 \\ .2482 & -2 \\ \end{array}$
17. 62	.5013 -6	.3163 -4	. 1585 -1	17. 59	.1090 -3	8248	2. 4300004	114. 29	3. 254	. 3811	362. 0	5. 905	61. 31	. 2006 -3	
17. 64	.4973 -6	.3145 -4	. 1581 -1	17. 61	.1083 -3	8295	2. 4300441	114. 31	3. 250	. 3811	362. 9	5. 905	61. 45	. 1995 -3	
17. 66	.4935 -6	.3128 -4	. 1578 -1	17. 63	.1077 -3	8341	2. 4300876	114. 33	3. 246	. 3811	363. 7	5. 905	61. 59	. 1984 -3	
17. 68	.4897 -6	.3110 -4	. 1574 -1	17. 65	.1071 -3	8387	2. 4301309	114. 35	3. 242	. 3811	364. 5	5. 906	61. 72	. 1973 -3	

## TABLE II.—SUPERSONIC FLOW—Continued

$M$ or $M_1$	$\frac{p}{p_t}$	<u>ρ</u>	$\frac{T}{T_t}$	β	$\frac{q}{p_i}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	M <sub>2</sub>	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$\frac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{t_2}}$
17. 70 17. 72 17. 74 17. 76 17. 78	.4859 -6 .4821 -6 .4783 -6 .4747 -6 .4710 -6	. 3093 -4 . 3076 -4 . 3059 -4 . 3042 -4 . 3025 -4	.1571 -1 .1567 -1 .1564 -1 .1561 -1 .1557 -1	17. 67 17. 69 17. 71 17. 73 17. 75	$\begin{array}{cccc} .1066 & ^{-3} \\ .1060 & ^{-3} \\ .1054 & ^{-3} \\ .1048 & ^{-3} \\ .1042 & ^{-3} \end{array}$	8434 8481 8529 8575 8623	2. 4301741 2. 4302172 2. 4302601 2. 4303029 2. 4303455	114. 36 114. 38 114. 40 114. 42 114. 44	3. 239 3. 235 3. 231 3. 228 3. 224	. 3811 . 3810 . 3810 . 3810 . 3810	365. 3 366. 2 367. 0 367. 8 368. 7	5. 906 5. 906 5. 906 5. 906 5. 907	61. 86 62. 00 62. 14 62. 28 62. 41	.1962 -3 .1951 -3 .1941 -3 .1930 -3 .1919 -3	$\begin{array}{ccccc} .2476 & -2 \\ .2471 & -2 \\ .2465 & -2 \\ .2460 & -2 \\ .2454 & -2 \\ \end{array}$
17. 80	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	.3009 -4	. 1554 -1	17. 77	. 1037 -3	8670	2. 4303880	114. 45	3. 221	. 3810	369. 5	5. 907	62, 55	.1909 -3	. 2449 -2
17. 82		.2992 -4	. 1550 -1	17. 79	. 1031 -3	8719	2. 4304304	114. 47	3. 217	. 3810	370. 3	5. 907	62, 69	.1898 -3	. 2443 -2
17. 84		.2975 -4	. 1547 -1	17. 81	. 1025 -3	8767	2. 4304726	114. 49	3. 213	. 3810	371. 1	5. 907	62, 83	.1888 -3	. 2437 -2
17. 86		.2959 -4	. 1543 -1	17. 83	. 1020 -3	8815	2. 4305147	114. 51	3. 210	. 3810	372. 0	5. 907	62, 97	.1878 -3	. 2432 -2
17. 88		.2943 -4	. 1540 -1	17. 85	. 1014 -3	8864	2. 4305566	114. 52	3. 206	. 3810	372. 8	5. 908	63, 11	.1867 -3	. 2427 -2
17. 90	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 2926 -4	.1537 -1	17. 87	.1009 -3	8913	2. 4305984	114. 54	3. 203	. 3810	373. 7	5. 908	63, 25	. 1857 -3	. 2421 -2
17. 92		. 2910 -4	.1533 -1	17. 89	.1003 -3	8962	2. 4306401	114. 56	3. 199	. 3810	374. 5	5. 908	63, 39	.1847 -3	. 2416 -2
17. 94		. 2895 -4	.1530 -1	17. 91	.9976 -4	9010	2. 4306816	114. 58	3. 195	. 3810	375. 3	5. 908	63, 53	.1837 -3	. 2411 -2
17. 96		. 2879 -4	.1526 -1	17. 93	.9921 -4	9060	2. 4307230	114. 59	3. 192	. 3810	376. 2	5. 908	63, 67	.1827 -3	. 2405 -2
17. 98		. 2863 -4	.1523 -1	17. 95	.9868 -4	9109	2. 4307642	114. 61	3. 188	. 3810	377. 0	5. 909	63, 80	.1817 -3	. 2400 -2
18.00 18.02 18.04 18.06 18.06	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 2848 -4 . 2332 -4 . 2816 -4 . 2801 -4 . 2786 -4	$\begin{array}{cccc} .1520 & ^{-1}\\ .1516 & ^{-1}\\ .1513 & ^{-1}\\ .1510 & ^{-1}\\ .1507 & ^{-1}\\ \end{array}$	17. 97 17. 99 18. 01 18. 03 18. 05	. 9815 -4 . 9760 -4 . 9707 -4 . 9655 -4 . 9602 -4	9159 9210 9260 9311 9362	2. 4308053 2. 4308463 2. 4308872 2. 4309279 2. 4309685	114. 63 114. 65 114. 66 114. 68 114. 70	3. 185 3. 181 3. 178 3. 174 3. 171	. 3810 . 3809 . 3809 . 3809 . 3809	377. 8 378. 7 379. 5 380. 4 381. 2	5. 909 5. 909 5. 909 5. 909 5. 910	63. 94 64. 08 64. 23 64. 37 64. 51	.1807 -3 .1797 -3 .1788 -3 .1778 -3 .1768 -3	. 2395 -2 . 2389 -2 . 2384 -2 . 2379 -2 . 2373 -2
18. 10 18. 12 18. 14 18. 16 18. 18	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 2771 -4 . 2756 -4 . 2741 -4 . 2726 -4 . 2711 -4	.1503 -1 .1500 -1 .1497 -1 .1494 -1 .1490 -1	18. 07 18. 09 18. 11 18. 13 18. 15	.9552 -4 .9500 -4 .9448 -4 .9398 -4 .9349 -4	9411 9463 9515 9566 9617	2. 4310089 2. 4310492 2. 4310894 2. 4311295 2. 4311694	114. 72 114. 73 114. 75 114. 77 114. 78	3. 167 3. 164 3. 160 3. 157 3. 153	. 3809 . 3809 . 3809 . 3809 . 3809	382. 1 382. 9 383. 7 384. 6 385. 4	5. 910 5. 910 5. 910 5. 910 5. 911	64. 65 64. 79 64. 93 65. 07 65. 21	.1759 -3 .1749 -3 .1740 -3 .1731 -3 .1721 -3	$\begin{array}{cccc} .2368 & -2 \\ .2363 & -2 \\ .2357 & -2 \\ .2353 & -2 \\ .2348 & -2 \\ \end{array}$
18. 20	. 4010 -6	. 2696 -4	. 1487 -1	18. 17	.9297 -4	9671	2. 4312092	114. 80	3. 150	. 3809	386. 3	5. 911	65. 35	.1712 -3	. 2342 -2
18. 22	. 3979 -6	. 2682 -4	. 1484 -1	18. 19	.9247 -4	9723	2. 4312488	114. 82	3. 146	. 3809	387. 1	5. 911	65. 49	.1703 -3	. 2337 -2
18. 24	. 3949 -6	. 2667 -4	. 1481 -1	18. 21	.9198 -4	9775	2. 4312884	114. 83	3. 143	. 3809	388. 0	5. 911	65. 64	.1694 -3	. 2332 -2
18. 26	. 3920 -6	. 2653 -4	. 1477 -1	18. 23	.9148 -4	9828	2. 4313278	114. 85	3. 139	. 3809	388. 8	5. 911	65. 78	.1685 -3	. 2327 -2
18. 28	. 3890 -6	. 2639 -4	. 1474 -1	18. 25	.9099 -4	9881	2. 4313671	114. 87	3. 136	. 3809	389. 7	5. 912	65. 92	.1676 -3	. 2321 -2
18. 30	.3861 -6	. 2625 -4	. 1471 -1	18. 27	. 9052 -4	9933	2. 4314062	114. 89	3. 133	. 3809	390. 5	5. 912	66, 06	.1667 -3	$\begin{array}{ccccc} .\ 2317 & -2 \\ .\ 2312 & -2 \\ .\ 2306 & -2 \\ .\ 2302 & -2 \\ .\ 2297 & -2 \\ \end{array}$
18. 32	.3832 -6	. 2611 -4	. 1468 -1	18. 29	. 9003 -4	9987	2. 4314452	114. 90	3. 129	. 3809	391. 4	5. 912	66, 20	.1658 -3	
18. 34	.3803 -6	. 2596 -4	. 1465 -1	18. 31	. 8954 -4	1004 +1	2. 4314841	114. 92	3. 126	. 3808	392. 3	5. 912	66, 35	.1649 -3	
18. 36	.3775 -6	. 2583 -4	. 1462 -1	18. 33	. 8907 -4	1010 +1	2. 4315229	114. 94	3. 122	. 3808	393. 1	5. 912	66, 49	.1640 -3	
18. 38	.3747 -6	. 2569 -4	. 1459 -1	18. 35	. 8861 -4	1015 +1	2. 4315616	114. 95	3. 119	. 3808	394. 0	5. 913	66, 63	.1632 -3	
18. 40	.3718 -6	. 2555 -4	. 1455 -1	18. 37	. 8812 -4	1020 +1	2. 4316001	114. 97	3. 115	. 3808	394. 8	5. 913	66. 78	.1623 -3	. 2291 -2
18. 42	.3691 -6	. 2541 -4	. 1452 -1	18. 39	. 8765 -4	1026 +1	2. 4316385	114. 99	3. 112	. 3808	395. 7	5. 913	66. 92	.1614 -3	. 2287 -2
18. 44	.3663 -6	. 2528 -4	. 1449 -1	18. 41	. 8719 -4	1031 +1	2. 4316768	115. 00	3. 109	. 3808	396. 5	5. 913	67. 06	.1606 -3	. 2281 -2
18. 46	.3636 -6	. 2514 -4	. 1446 -1	18. 43	. 8673 -4	1037 +1	2. 4317149	115. 02	3. 105	. 3808	397. 4	5. 913	67. 21	.1597 -3	. 2277 -2
18. 48	.3609 -6	. 2501 -4	. 1443 -1	18. 45	. 8628 -4	1042 +1	2. 4317530	115. 04	3. 102	. 3808	398. 3	5. 913	67. 35	.1589 -3	. 2272 -2
18. 50	.3582 -6	. 2488 -4	. 1440 -1	18. 47	. 8582 -4	1048 +1	2. 4317909	115. 05	3. 099	. 3808	399. 1	5. 914	67. 49	.1580 -3	$\begin{array}{ccccc} .\ 2267 & -2 \\ .\ 2262 & -2 \\ .\ 2257 & -2 \\ .\ 2252 & -2 \\ .\ 2248 & -2 \\ \end{array}$
18. 52	.3555 -6	. 2475 -4	. 1437 -1	18. 49	. 8536 -4	1054 +1	2. 4318287	115. 07	3. 095	. 3808	400. 0	5. 914	67. 64	.1572 -3	
18. 54	.3530 -6	. 2462 -4	. 1434 -1	18. 51	. 8492 -4	1059 +1	2. 4318664	115. 08	3. 092	. 3808	400. 9	5. 914	67. 78	.1564 -3	
18. 56	.3503 -6	. 2448 -4	. 1431 -1	18. 53	. 8446 -4	1065 +1	2. 4319039	115. 10	3. 089	. 3808	401. 7	5. 914	67. 93	.1555 -3	
18. 58	.3477 -6	. 2436 -4	. 1428 -1	18. 55	. 8403 -4	1070 +1	2. 4319413	115. 12	3. 085	. 3808	402. 6	5. 914	68. 07	.1547 -3	
18. 60	. 3452 -6	. 2423 -4	. 1425 -1	18. 57	. 8359 -4	1076 +1	2. 4319787	115. 13	3. 082	. 3808	403. 5	5. 915	68. 21	.1539 -3	. 2243 -2
18. 62	. 3426 -6	. 2410 -4	. 1422 -1	18. 59	. 8315 -4	1082 +1	2. 4320159	115. 15	3. 079	. 3808	404. 3	5. 915	68. 36	.1531 -3	. 2238 -2
18. 64	. 3400 -6	. 2397 -4	. 1419 -1	18. 61	. 8270 -4	1088 +1	2. 4320529	115. 17	3. 075	. 3808	405. 2	5. 915	68. 50	.1523 -3	. 2233 -2
18. 66	. 3375 -6	. 2384 -4	. 1416 -1	18. 63	. 8226 -4	1093 +1	2. 4320899	115. 18	3. 072	. 3807	406. 1	5. 915	68. 65	.1515 -3	. 2228 -2
18. 68	. 3351 -6	. 2372 -4	. 1413 -1	18. 65	. 8185 -4	1099 +1	2. 4321267	115. 20	3. 069	. 3807	406. 9	5. 915	68. 79	.1507 -3	. 2224 -2
18. 70	. 3326 -6	. 2359 -4	. 1410 -1	18. 67	. 8142 -4	1105 +1	2. 4321635	115. 21	3. 065	. 3807	407. 8	5. 915	68. 94	.1499 -3	$\begin{array}{ccccc} .\ 2219 & -2 \\ .\ 2214 & -2 \\ .\ 2209 & -2 \\ .\ 2205 & -2 \\ .\ 2200 & -2 \\ \end{array}$
18. 72	. 3301 -5	. 2347 -4	. 1407 -1	18. 69	. 8099 -4	1111 +1	2. 4322001	115. 23	3. 062	. 3807	408. 7	5. 916	69. 09	.1491 -3	
18. 74	. 3278 -6	. 2335 -4	. 1404 -1	18. 71	. 8058 -4	1116 +1	2. 4322366	115. 25	3. 059	. 3807	409. 6	5. 916	69. 23	.1484 -3	
18. 76	. 3253 -6	. 2322 -4	. 1401 -1	18. 73	. 8015 -4	1122 +1	2. 4322729	115. 26	3. 056	. 3807	410. 4	5. 916	69. 38	.1476 -3	
18. 78	. 3230 -6	. 2310 -4	. 1398 -1	18. 75	. 7974 -4	1128 +1	2. 4323092	115. 28	3. 052	. 3807	411. 3	5. 916	69. 52	.1468 -3	
18. 80	. 3206 -6	. 2298 -4	. 1395 -1	18. 77	. 7931 -4	1134 +1	2. 4323454	115. 29	3. 049	. 3807	412. 2	5. 916	69. 67	.1460 -3	$\begin{array}{ccccc} .2195 & -2 \\ .2191 & -2 \\ .2186 & -2 \\ .2182 & -2 \\ .2177 & -2 \end{array}$
18. 82	. 3182 -6	. 2286 -4	. 1392 -1	18. 79	. 7890 -4	1140 +1	2. 4323814	115. 31	3. 046	. 3807	413. 1	5. 917	69. 82	.1453 -3	
18. 84	. 3159 -6	. 2274 -4	. 1389 -1	18. 81	. 7849 -4	1146 +1	2. 4324173	115. 33	3. 043	. 3807	413. 9	5. 917	69. 96	.1445 -3	
18. 86	. 3136 -6	. 2262 -4	. 1386 -1	18. 83	. 7809 -4	1152 +1	2. 4324531	115. 34	3. 039	. 3807	414. 8	5. 917	70. 11	.1438 -3	
18. 88	. 3113 -6	. 2251 -4	. 1383 -1	18. 85	. 7768 -4	1158 +1	2. 4324888	115. 36	3. 036	. 3807	415. 7	5. 917	70. 26	.1430 -3	
18. 90	. 3090 -6	. 2239 -4	. 1380 -1	18. 87	. 7727 -4	1164 +1	2. 4325244	115. 38	3. 033	. 3807	416. 6	5. 917	70. 40	.1423 -3	$\begin{array}{cccc} .2172 & -2 \\ .2167 & -2 \\ .2163 & -2 \\ .2158 & -2 \\ .2154 & -2 \\ \end{array}$
18. 92	. 3068 -6	. 2227 -4	. 1378 -1	18. 89	. 7687 -4	1170 +1	2. 4325599	115. 39	3. 030	. 3807	417. 5	5. 917	70. 55	.1416 -3	
18. 94	. 3046 -6	. 2216 -4	. 1375 -1	18. 91	. 7649 -4	1176 +1	2. 4325953	115. 41	3. 027	. 3807	418. 3	5. 918	70. 70	.1408 -3	
18. 96	. 3024 -6	. 2204 -4	. 1372 -1	18. 93	. 7608 -4	1182 +1	2. 4326305	115. 42	3. 023	. 3807	419. 2	5. 918	70. 84	.1401 -3	
18. 98	. 3002 -8	. 2193 -4	. 1369 -1	18. 95	. 7570 -4	1188 +1	2. 4326657	115. 44	3. 020	. 3807	420. 1	5. 918	70. 99	.1394 -3	
19.00	. 2980 -6	. 2181 -4	. 1366 -1	18. 97	. 7530 -4	1195 +1	2. 4327007	115. 45	3. 017	.3806	421. 0	5. 918	71. 14	.1387 -3	. 2149 -2
19.02	. 2959 -6	. 2170 -4	. 1363 -1	18. 99	. 7492 -4	1201 +1	2. 4327356	115. 47	3. 014	.3806	421. 9	5. 918	71. 29	.1379 -3	. 2145 -2
19.04	. 2937 -6	. 2159 -4	. 1361 -1	19. 01	. 7454 -4	1207 +1	2. 4327705	115. 48	3. 011	.3806	422. 8	5. 918	71. 44	.1372 -3	. 2141 -2
19.06	. 2915 -6	. 2148 -4	. 1358 -1	19. 03	. 7414 -4	1213 +1	2. 4328052	115. 50	3. 008	.3806	423. 7	5. 919	71. 58	.1365 -3	. 2136 -2
19.08	. 2894 -6	. 2136 -4	. 1355 -1	19. 05	. 7376 -4	1220 +1	2. 4328398	115. 52	3. 004	.3806	424. 6	5. 919	71. 73	.1358 -3	. 2131 -2
19. 10	. 2874 -6	. 2125 -4	. 1352 -1	19. 07	. 7338 -4	1226 +1	2. 4328743	115. 53	3. 001	. 3806	425. 5	5. 919	71, 88	. 1351 -3	. 2127 -2
19. 12	. 2854 -6	. 2115 -4	. 1349 -1	19. 09	. 7302 -4	1232 +1	2. 4329087	115. 55	2. 998	. 3806	426. 3	5. 919	72, 03	. 1344 -3	. 2123 -2
19. 14	. 2833 -6	. 2104 -4	. 1347 -1	19. 11	. 7264 -4	1239 +1	2. 4329430	115. 56	2. 995	. 3806	427. 2	5. 919	72, 18	. 1337 -3	. 2118 -2
19. 16	. 2812 -6	. 2093 -4	. 1344 -1	19. 13	. 7227 -4	1245 +1	2. 4329771	115. 58	2. 992	. 3806	428. 1	5. 919	72, 33	. 1331 -3	. 2114 -2
19. 18	. 2792 -6	. 2082 -4	. 1341 -1	19. 15	. 7189 -4	1252 +1	2. 4330112	115. 59	2. 989	. 3806	429. 0	5. 920	72, 48	. 1324 -3	. 2109 -2
19. 20 19. 22 19. 24 19. 26 19. 28	. 2772 -6 . 2752 -6 . 2733 -6 . 2713 -6 . 2694 -6	. 2072 -4 . 2061 -4 . 2050 -4 . 2040 -4 . 2030 -4	. 1338 -1 . 1335 -1 . 1333 -1 . 1330 -1 . 1327 -1	19. 17 19. 19 19. 21 19. 23 19. 25	.7154 -4 .7116 -4 .7081 -4 .7045 -4 .7010 -4	1258 +1 1264 +1 1271 +1 1277 +1 1284 +1	2. 4330452 2. 4330790 2. 4331128 2. 4331464 2. 4331800	115. 61 115. 62 115. 64 115. 65 115. 67	2. 986 2. 982 2. 979 2. 976 2. 973	. 3806 . 3806 . 3806 . 3806 . 3806	429. 9 430. 8 431. 7 432. 6 433. 5	5. 920 5. 920 5. 920 5. 920 5. 920 5. 920	72. 62 72. 77 72. 92 73. 07 73. 22	. 1317 -3 . 1310 -3 . 1304 -3 . 1297 -3 . 1291 -3	. 2105 -2 . 2100 -2 . 2096 -2 . 2092 -2 . 2088 -2
19. 30	. 2674 -6	. 2019 -4	. 1325 -1	19. 27	. 6973 -4	1291 +1	2. 4332135	115. 68	2, 970	. 3806	434. 4	5. 921	73. 37	. 1284 -3	. 2083 -2
19. 32	. 2655 -6	. 2009 -4	. 1322 -1	19. 29	. 6937 -4	1297 +1	2. 4332468	115. 70	2, 967	. 3806	435. 3	5. 921	73. 52	. 1277 -3	. 2079 -2
19. 34	. 2636 -6	. 1999 -4	. 1319 -1	19. 31	. 6902 -4	1304 +1	2. 4332800	115. 71	2, 964	. 3806	436. 2	5. 921	73. 67	. 1271 -3	. 2074 -2
19. 36	. 2617 -6	. 1988 -4	. 1316 -1	19. 33	. 6867 -4	1310 +1	2. 4333132	115. 73	2, 961	. 3805	437. 1	5. 921	73. 82	. 1265 -3	. 2070 -2
19. 38	. 2599 -6	. 1979 -4	. 1314 -1	19. 35	. 6834 -4	1317 +1	2. 4333462	115. 74	2, 958	. 3805	438. 0	5. 921	73. 98	. 1258 -3	. 2066 -2
19. 40 19. 42 19. 44 19. 46 19. 48	. 2581 -6 . 2562 -6 . 2544 -6 . 2526 -6 . 2508 -6	.1968 -4 .1958 -4 .1949 -4 .1938 -4 .1929 -4	. 1311 -1 . 1308 -1 . 1306 -1 . 1303 -1 . 1301 -1	19, 37 19, 39 19, 41 19, 43 19, 45	.6799 -4 .6764 -4 .6731 -4 .6696 -4 .6663 -4	1324 +1 1330 +1 1337 +1 1344 +1 1351 +1	2. 4333792 2. 4334120 2. 4334447 2. 4334774 2. 4335099	115. 76 115. 78 115. 79 115. 80 115. 82	2, 955 2, 952 2, 949 2, 946 2, 943	. 3805 . 3805 . 3805 . 3805 . 3805	438. 9 439. 8 440. 7 441. 6 442. 6	5. 921 5. 922 5. 922 5. 922 5. 922	74. 13 74. 28 74. 43 74. 58 74. 73	$\begin{array}{cccc} .1252 & ^{-3}\\ .1245 & ^{-3}\\ .1239 & ^{-3}\\ .1233 & ^{-3}\\ .1227 & ^{-3}\\ \end{array}$	$\begin{array}{cccc} .2062 & -2 \\ .2057 & -2 \\ .2053 & -2 \\ .2049 & -2 \\ .2045 & -2 \\ \end{array}$

### TABLE II.—SUPERSONIC FLOW—Continued

							$\gamma = 7/5$								
M or M <sub>1</sub>	$\frac{p}{p_t}$	<u>ρ</u> ρι	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$rac{p_1}{p_{t_2}}$
19. 50	. 2491 -6	.1919 -4	.1298 -1	19. 47	.6630 -4	1357 +1	2. 4335424	115. 83	2. 940	. 3805	443. 5	5. 922	74. 88	.1221 -3	. 2041 -2
19. 52	. 2473 -6	.1909 -4	.1295 -1	19. 49	.6595 -4	1365 +1	2. 4335747	115. 85	2. 937	. 3805	444. 4	5. 922	75. 03	.1214 -3	. 2036 -2
19. 54	. 2455 -6	.1900 -4	.1293 -1	19. 51	.6563 -4	1371 +1	2. 4336070	115. 86	2. 934	. 3805	445. 3	5. 922	75. 19	.1208 -3	. 2032 -2
19. 56	. 2438 -6	.1890 -4	.1290 -1	19. 53	.6530 -4	1378 +1	2. 4336391	115. 88	2. 931	. 3805	446. 2	5. 923	75. 34	.1202 -3	. 2028 -2
19. 58	. 2421 -6	.1881 -4	.1287 -1	19. 55	.6497 -4	1385 +1	2. 4336712	115. 89	2. 928	. 3805	447. 1	5. 923	75. 49	.1196 -3	. 2024 -2
19. 60	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	. 1871 -4	.1285 -1	19. 57	.6464 -4	1392 +1	2. 4337031	115. 91	2, 925	. 3805	448. 0	5. 923	75. 64	.1190 -3	. 2020 -2
19. 62		. 1862 -4	.1282 -1	19. 59	.6432 -4	1399 +1	2. 4337350	115. 92	2, 922	. 3805	448. 9	5. 923	75. 80	.1184 -3	. 2016 -2
19. 64		. 1853 -4	.1280 -1	19. 61	.6401 -4	1406 +1	2. 4337667	115. 94	2, 919	. 3805	449. 9	5. 923	75. 95	.1178 -3	. 2012 -2
19. 66		. 1843 -4	.1277 -t	19. 63	.6369 -4	1413 +1	2. 4337984	115. 95	2, 916	. 3805	450. 8	5. 923	76. 10	.1173 -3	. 2008 -2
19. 68		. 1834 -4	.1275 -1	19. 65	.6336 -4	1420 +1	2. 4338300	115. 97	2, 913	. 3805	451. 7	5. 924	76. 25	.1167 -3	. 2003 -2
19. 70	.2321 -6	.1825 -4	.1272 -1	19. 67	.6306 -4	1427 +1	2. 4338615	115. 98	2. 910	. 3805	452. 6	5. 924	76. 41	. 1161 -3	. 2000 -2
19. 72	.2305 -6	.1816 -4	.1269 -1	19. 69	.6274 -4	1435 +1	2. 4338928	116. 00	2. 907	. 3805	453. 5	5. 924	76. 56	. 1155 -3	. 1995 -2
19. 74	.2289 -6	.1807 -4	.1267 -1	19. 72	.6243 -4	1442 +1	2. 4339241	116. 01	2. 904	. 3805	454. 5	5. 924	76. 71	. 1149 -3	. 1991 -2
19. 76	.2273 -6	.1798 -4	.1264 -1	19. 74	.6213 -4	1449 +1	2. 4339553	116. 03	2. 901	. 3804	455. 4	5. 924	76. 87	. 1144 -3	. 1988 -2
19. 78	.2257 -6	.1788 -4	.1262 -1	19. 76	.6180 -4	1456 +1	2. 4339864	116. 04	2. 898	. 3804	456. 3	5. 924	77. 02	. 1138 -3	. 1983 -2
19. 80	. 2241 -6	.1780 -4	. 1259 -1	19. 78	.6150 -4	1464 +1	2. 4340174	116. 05	2. 895	. 3804	457. 2	5. 924	77. 17	.1132 -3	$\begin{array}{cccc} .1979 & -2 \\ .1975 & -2 \\ .1971 & -2 \\ .1967 & -2 \\ .1963 & -3 \\ \end{array}$
19. 82	. 2226 -6	.1771 -4	. 1257 -1	19. 80	.6120 -4	1471 +1	2. 4340483	116. 07	2. 892	. 3804	458. 1	5. 925	77. 33	.1127 -3	
19. 84	. 2210 -6	.1762 -4	. 1254 -1	19. 82	.6090 -4	1478 +1	2. 4340792	116. 08	2. 889	. 3804	459. 1	5. 925	77. 48	.1121 -3	
19. 86	. 2195 -6	.1753 -4	. 1252 -1	19. 84	.6059 -4	1486 +1	2. 4341099	116. 10	2. 886	. 3804	460. 0	5. 925	77. 64	.1116 -3	
19. 88	. 2179 -6	.1745 -4	. 1249 -1	19. 86	.6029 -4	1493 +1	2. 4341405	116. 11	2. 883	. 3804	460. 9	5. 925	77. 79	.1110 -3	
19. 90	. 2165 -6	.1736 -4	. 1247 -1	19. 88	. 6001 -4	1500 +1	2. 4341711	116. 13	2. 880	. 3804	461. 9	5. 925	77. 95	.1105 -3	$\begin{array}{cccc} .1960 & -2 \\ .1956 & -2 \\ .1952 & -2 \\ .1948 & -2 \\ .1944 & -2 \\ \end{array}$
19. 92	. 2150 -6	.1727 -4	. 1244 -1	19. 90	. 5971 -4	1508 +1	2. 4342015	116. 14	2. 878	. 3804	462. 8	5. 925	78. 10	.1099 -3	
19. 94	. 2135 -6	.1719 -4	. 1242 -1	19. 92	. 5941 -4	1515 +1	2. 4342319	116. 15	2. 875	. 3804	463. 7	5. 926	78. 26	.1094 -3	
19. 96	. 2120 -6	.1710 -4	. 1249 -1	19. 94	. 5913 -4	1523 +1	2. 4342622	116. 17	2. 872	. 3804	464. 6	5. 926	78. 41	.1088 -3	
19. 98	. 2105 -6	.1702 -4	. 1237 -1	19. 96	. 5883 -4	1530 +1	2. 4342924	116. 18	2. 869	. 3804	465. 6	5. 926	78. 57	.1083 -3	
20. 00 20. 20 20. 40 20. 60 20. 80	$\begin{array}{ccccc} .2091 & -6 \\ .1952 & -6 \\ .1823 & -6 \\ .1704 & -6 \\ .1594 & -6 \\ \end{array}$	. 1694 -4 . 1612 -4 . 1536 -4 . 1463 -4 . 1395 -4	. 1235 -1 . 1211 -1 . 1187 -1 . 1165 -1 . 1143 -1	19. 98 20. 18 29. 38 29. 58 20. 78	. 5855 -4 . 5574 -4 . 5311 -4 . 5062 -4 . 4827 -4	1538 +1 1615 +1 1695 +1 1779 +1 1866 +1	2. 4343225 2. 4346186 2. 4349062 2. 4351855 2. 4354569	116. 20 116. 34 116. 47 116. 61 116. 74	2. 866 2. 838 2. 810 2. 782 2. 756	. 3804 . 3803 . 3803 . 3802 . 3802	466. 5 475. 9 485. 4 494. 9 504. 6	5. 926 5. 927 5. 929 5. 930 5. 932	78. 72 80. 29 81. 86 83. 46 85. 07	. 1078 -3 . 1026 -3 . 9778 -4 . 9319 -4 . 8887 -4	$\begin{array}{cccc} .1940 & -2 \\ .1902 & -2 \\ .1865 & -2 \\ .1829 & -2 \\ .1794 & -2 \\ \end{array}$
21. 00	$\begin{array}{cccc} .1492 & -6 \\ .1397 & -6 \\ .1399 & -6 \\ .1227 & -6 \\ .1151 & -6 \\ \end{array}$	.1331 -4	. 1121 -1	20. 98	. 4606 -4	1956 +1	2. 4357207	116. 87	2. 729	. 3802	514. 3	5. 933	86. 69	.8478 -4	. 1769 -2
21. 20		.1270 -4	. 1100 -1	21. 18	. 4396 -4	2049 +1	2. 4359772	117. 00	2. 704	. 3801	524. 2	5. 934	88. 34	.8091 -4	. 1727 -2
21. 40		.1212 -4	. 1089 -1	21. 38	. 4197 -4	2147 +1	2. 4362265	117. 12	2. 678	. 3801	534. 1	5. 935	89. 99	.7725 -4	. 1695 -2
21. 60		.1158 -4	. 1069 -1	21. 58	. 4009 -4	2248 +1	2. 4364690	117. 24	2. 654	. 3800	544. 2	5. 936	91. 66	.7380 -4	. 1663 -2
21. 80		.1106 -4	. 1041 -1	21. 78	. 3830 -4	2353 +1	2. 4367050	117. 36	2. 629	. 3800	554. 3	5. 938	93. 35	.7052 -4	. 1633 -2
22. 00	. 1081 -6	. 1057 -4	. 1023 -1	21. 98	. 3662 -4	2461 +1	2. 4369346	117. 48	2. 605	. 3800	564. 5	5. 939	95. 05	. 6742 -4	$\begin{array}{cccc} .1604 & -2 \\ .1575 & -2 \\ .1547 & -2 \\ .1520 & -2 \\ .1493 & -2 \\ \end{array}$
22. 20	. 1015 -6	. 1011 -4	. 1004 -1	22. 18	. 3502 -4	2574 +1	2. 4371581	117. 69	2. 582	. 3799	574. 8	5. 940	96. 77	. 6447 -4	
22. 40	. 9541 -7	. 9670 -5	. 9867 -2	22. 38	. 3351 -4	2690 +1	2. 4373757	117. 71	2. 559	. 3799	585. 2	5. 941	98. 51	. 6168 -4	
22. 60	. 8971 -7	. 9253 -5	. 9694 -2	22. 58	. 3207 -4	2811 +1	2. 4375876	117. 82	2. 536	. 3799	595. 7	5. 942	100. 3	. 5904 -4	
22. 80	. 8439 -7	. 8858 -5	. 9527 -2	22. 78	. 3071 -4	2936 +1	2. 4377940	117. 93	2. 514	. 3798	606. 3	5. 943	102. 0	. 5653 -4	
23. 00	. 7943 -7	. 8483 -5	. 9363 -2	22. 98	. 2941 -4	3065 +1	2. 4379951	118. 04	2. 492	. 3798	617. 0	5. 944	103. 8	. 5414 -4	$\begin{array}{ccccc} .1467 & -2 \\ .1442 & -2 \\ .1418 & -2 \\ .1394 & -2 \\ .1370 & -2 \\ \end{array}$
23. 20	. 7489 -7	. 8127 -5	. 9204 -2	23. 18	. 2818 -4	3199 +1	2. 4381911	118. 15	2. 470	. 3798	627. 8	5. 945	105. 6	. 5188 -4	
23. 40	. 7048 -7	. 7789 -5	. 9049 -2	23. 38	. 2701 -4	3338 +1	2. 4383821	118. 25	2. 449	. 3797	638. 7	5. 946	107. 4	. 4972 -4	
23. 60	. 6644 -7	. 7467 -5	. 8897 -2	23. 58	. 2590 -4	3481 +1	2. 4385683	118. 36	2. 429	. 3797	649. 6	5. 947	109. 2	. 4768 -4	
23. 80	. 6266 -7	. 7161 -5	. 8750 -2	23. 78	. 2485 -4	3630 +1	2. 4387499	118. 46	2. 408	. 3797	669. 7	5. 948	111. 1	. 4573 -4	
24. 00	. 5913 -7	. 6871 -5	. 8696 -2	23. 98	. 2384 -4	3783 +1	2. 4389270	118. 56	2. 388	. 3796	671. 8	5. 948	112. 9	. 4388 -4	$\begin{array}{cccc} .1348 & -2 \\ .1325 & -2 \\ .1304 & -2 \\ .1283 & -2 \\ .1262 & -2 \end{array}$
24. 20	. 5582 -7	. 6594 -5	. 8465 -2	24. 18	. 2288 -4	3942 +1	2. 4390998	118. 65	2. 368	. 3796	683. 1	5. 949	114. 8	. 4211 -4	
24. 40	. 5272 -7	. 6330 -5	. 8328 -2	24. 38	. 2197 -4	4106 +1	2. 4392683	118. 75	2. 349	. 3796	694. 4	5. 950	116. 7	. 4044 -4	
24. 60	. 4981 -7	. 6079 -5	. 8195 -2	24. 58	. 2110 -4	4275 +1	2. 4394328	118. 85	2. 339	. 3796	705. 9	5. 951	118. 6	. 3884 -4	
24. 80	. 4709 -7	. 5839 -5	. 8964 -2	24. 78	. 2027 -4	4450 +1	2. 4395334	118. 94	2. 311	. 3795	717. 4	5. 952	120. 5	. 3731 -4	
25. 00 25. 20 25. 49 25. 60 25. 80	. 4454 -7 . 4214 -7 . 3989 -7 . 3777 -7 . 3578 -7	. 5611 -5 . 5394 -5 . 5187 -5 . 4988 -5 . 4800 -5	$\begin{array}{cccc} .7937 & -2 \\ .7812 & -2 \\ .7690 & -2 \\ .7572 & -2 \\ .7456 & -2 \end{array}$	24. 98 25. 18 25. 38 25. 58 25. 78	. 1948 -4 . 1873 -4 . 1891 -4 . 1733 -4 . 1667 -4	4631 +1 4817 +1 5009 +1 5208 +1 5412 +1	2. 4397502 2. 4399033 2, 4400528 2. 4401988 2. 4403415	119. 03 119. 12 119. 21 119. 30 119. 38	2. 292 2. 274 2. 256 2. 239 2. 221	. 3795 . 3795 . 3795 . 3794 . 3794	729. 0 740. 7 752. 5 764. 4 776. 4	5. 952 5. 953 5. 954 5. 955 5. 955	122. 5 124. 4 126. 4 128. 4 130. 4	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccc} .1242 & -2 \\ .1222 & -2 \\ .1203 & -2 \\ .1184 & -2 \\ .1166 & -2 \end{array}$
26. 03 26. 20 26. 40 26. 60 26. 80	. 3391 -7 . 3216 -7 . 3050 -7 . 2894 -7 . 2747 -7	. 4619 -5 . 4447 -5 . 4282 -5 . 4125 -5 . 3974 -5	$\begin{array}{cccc} .7342 & ^{-2}\\ .7231 & ^{-2}\\ .7123 & ^{-2}\\ .7017 & ^{-2}\\ .6913 & ^{-2}\\ \end{array}$	25. 98 26. 18 26. 38 26. 58 26. 78	. 1605 -4 . 1545 -4 . 1488 -4 . 1434 -4 . 1381 -4	5624 +1 5841 +1 6366 +1 6297 +1 6535 +1	2. 4404809 2. 4496172 2. 4407504 2. 4498896 2. 4410080	119. 47 119. 55 119. 63 119. 71 119. 79	2. 204 2. 187 2. 171 2. 154 2. 138	. 3794 . 3794 . 3794 . 3793 . 3793	788. 5 800. 7 813. 0 825. 3 837. 8	5. 956 5. 957 5. 957 5. 958 5. 959	132. 4 134. 4 136. 5 138. 5 140. 6	. 2953 -4 . 2844 -4 . 2739 -4 . 2638 -4 . 2542 -4	$\begin{array}{ccccc} .\ 1148 & -2 \\ .\ 1131 & -2 \\ .\ 1114 & -2 \\ .\ 1097 & -2 \\ .\ 1081 & -2 \\ \end{array}$
27. 00 27. 20 27. 40 27. 60 27. 89	. 2609 -7 . 2479 -7 . 2355 -7 . 2239 -7 . 2130 -7	. 3830 -5 . 3692 -5 . 3560 -5 . 3434 -5 . 3313 -5	$\begin{array}{cccc} .6812 & -2 \\ .6713 & -2 \\ .6616 & -2 \\ .6521 & -2 \\ .6428 & -2 \\ \end{array}$	26. 98 27. 18 27. 38 27. 58 27. 78	. 1331 -4 . 1284 -4 . 1238 -4 . 1194 -4 . 1152 -4	6781 +1 7033 +1 7294 +1 7562 +1 7837 +1	2. 4411325 2. 4412544 2. 4413736 2. 4414902 2. 4416043	119. 87 119. 95 120. 03 120. 10 120. 18	2. 123 2. 107 2. 092 2. 076 2. 061	. 3793 . 3793 . 3793 . 3792 . 3792	850. 3 863. 0 875. 7 888. 6 901. 5	5, 959 5, 960 5, 960 5, 961 5, 961	142. 7 144. 8 146. 9 149. 1 151. 2	$\begin{array}{ccccc} .2450 & -4 \\ .2362 & -4 \\ .2278 & -4 \\ .2197 & -4 \\ .2120 & -4 \\ \end{array}$	$\begin{array}{ccccc} .1065 & -2 \\ .1049 & -2 \\ .1034 & -2 \\ .1019 & -2 \\ .1005 & -2 \\ \end{array}$
28. 00	. 2026 -7	$\begin{array}{cccc} .3197 & -5 \\ .3086 & -5 \\ .2979 & -5 \\ .2877 & -5 \\ .2779 & -5 \end{array}$	. 6337 -2	27. 98	. 1112 -4	8121 +t	2. 4417160	120. 25	2. 047	. 3792	914. 5	5. 962	153. 4	. 2046 -4	. 9902 -3
28. 20	. 1928 -7		. 6248 -2	28. 18	. 1073 -4	8413 +t	2. 4418254	120. 32	2. 032	. 3792	927. 6	5. 963	155. 6	. 1975 -4	. 9762 -3
28. 40	. 1836 -7		. 6161 -2	28. 38	. 1036 -4	8713 +t	2. 4419325	120. 39	2. 018	. 3792	940. 8	5. 963	157. 8	. 1907 -4	. 9626 -3
28. 60	. 1748 -7		. 6376 -2	28. 58	. 1001 -4	9022 +t	2. 4420373	120. 46	2. 034	. 3792	954. 1	5. 964	160. 0	. 1842 -4	. 9491 -3
28. 89	. 1665 -7		. 5992 -2	28. 78	. 9669 -5	9340 +t	2. 4421400	120. 53	1. 990	. 3791	967. 5	5. 964	162. 2	. 1779 -4	. 9363 -3
29. 00	. 1587 -7	$\begin{array}{cccc} .2685 & -5 \\ .2595 & -5 \\ .2509 & -5 \\ .2425 & -5 \\ .2346 & -5 \\ \end{array}$	. 5910 -2	28. 98	. 9343 -5	9666 +1	2. 4422406	120. 60	1. 976	. 3791	981. 0	5. 965	164. 5	. 1719 -4	. 9232 -3
29. 20	. 1513 -7		. 5839 -2	29. 18	. 9030 -5	1000 +2	2. 4423391	129. 67	1. 963	. 3791	994. 6	5. 965	166. 7	. 1662 -4	. 9106 -3
29. 40	. 1443 -7		. 5751 -2	29. 38	. 8730 -5	1035 +2	2. 4424356	120. 73	1. 949	. 3791	1098	5. 966	169. 0	. 1606 -4	. 8983 -3
29. 60	. 1376 -7		. 5674 -2	29. 58	. 8440 -5	1070 +2	2. 4425302	120. 80	1. 936	. 3791	1022	5. 966	171. 3	. 1553 -4	. 8860 -3
29. 80	. 1313 -7		. 5599 -2	29. 78	. 8164 -5	1107 +2	2. 4426230	120. 86	1. 923	. 3791	1036	5. 966	173. 6	. 1502 -4	. 8743 -3
30. 00 30. 20 30. 40 30. 60 30. 80	. 1254 -7 . 1197 -7 . 1143 -7 . 1092 -7 . 1044 -7	$\begin{array}{cccc} .\ 2269 & ^{-5} \\ .\ 2195 & ^{-5} \\ .\ 2124 & ^{-5} \\ .\ 2056 & ^{-5} \\ .\ 1991 & ^{-5} \end{array}$	$\begin{array}{ccccc} .5525 & -2 \\ .5452 & -2 \\ .5381 & -2 \\ .5312 & -2 \\ .5243 & -2 \\ \end{array}$	29. 98 30. 18 30. 38 30. 58 30. 78	. 7897 -5 . 7641 -5 . 7395 -5 . 7158 -5 . 6931 -5	1144 +2 1182 +2 1222 +2 1262 +2 1304 +2	2. 4427138 2. 4428029 2. 4428902 2. 4429759 2. 4433599	120. 93 120. 99 121. 05 121. 11 121. 17	1. 910 1. 898 1. 885 1. 873 1. 861	. 3790 . 3790 . 3790 . 3790 . 3790	1050 1064 1078 1092 1107	5. 967 5. 967 5. 968 5. 968 5. 969	175. 9 178. 3 180. 6 183. 0 185. 4	. 1453 -4 . 1496 -4 . 1361 -4 . 1317 -4 . 1275 -4	. 8626 -3 . 8512 -3 . 8400 -3 . 8292 -3 . 8185 -3
31. 00 31. 20 31. 49 31. 69 31. 80	. 9977 -8 . 9540 -8 . 9124 -8 . 8730 -8 . 8354 -8	$\begin{array}{cccc} .1928 & ^{-5} \\ .1867 & ^{-5} \\ .1808 & ^{-5} \\ .1752 & ^{-5} \\ .1698 & ^{-5} \end{array}$	$\begin{array}{cccc} .5176 & -2 \\ .5110 & -2 \\ .5046 & -2 \\ .4982 & -2 \\ .4923 & -2 \end{array}$	30. 98 31. 18 31. 38 31. 58 31. 78	. 6711 -5 . 6500 -5 . 6297 -5 . 6102 -5 . 5914 -5	1346 +2 1390 +2 1435 +2 1481 +2 1528 +2	2. 4431423 2. 4432231 2. 4433023 2. 4433801 2. 4434564	121. 23 121. 29 121. 35 121. 41 121. 46	1. 849 1. 837 1. 825 1. 813 1. 802	. 3790 . 3790 . 3789 . 3789 . 3789	1121 1136 1150 1165 1180	5. 969 5. 969 5. 970 5. 970 5. 971	187. 8 190. 2 192. 7 195. 1 197. 6	. 1235 -4 . 1196 -4 . 1159 -4 . 1123 -4 . 1088 -4	. 8079 -3 . 7976 -3 . 7874 -3 . 7775 -3 . 7677 -3
32. 00 32. 20 32. 40 32. 60 32. 80	. 7997 -8 . 7658 -8 . 7334 -8 . 7026 -8 . 6733 -8	$\begin{array}{cccc} .1646 & ^{-5} \\ .1596 & ^{-5} \\ .1547 & ^{-5} \\ .1501 & ^{-5} \\ .1456 & ^{-5} \end{array}$	$\begin{array}{cccc} .4859 & -2 \\ .4799 & -2 \\ .4740 & -2 \\ .4683 & -2 \\ .4626 & -2 \\ \end{array}$	31. 98 32. 18 32. 38 32. 58 32. 78	. 5733 -5 . 5558 -5 . 5389 -5 . 5227 -5 . 5071 -5	1576 +2 1626 +2 1677 +2 1729 +2 1782 +2	2. 4435314 2. 4436049 2. 4436770 2. 4437479 2. 4438175	121. 52 121. 57 121. 63 121. 68 121. 74	1. 791 1. 780 1. 769 1. 758 1. 747	. 3789 . 3789 . 3789 . 3789 . 3789	1195 1210 1225 1240 1255	5. 971 5. 971 5. 972 5. 972 5. 972	200. 1 202. 6 205. 1 207. 6 210. 1	. 1055 -4 . 1023 -4 . 9916 -5 . 9618 -5 . 9330 -5	. 7583 -3 . 7488 -3 . 7396 -3 . 7305 -3 . 7217 -3

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## TABLE II.—SUPERSONIC FLOW—Continued

$egin{array}{c} m{M} \  ext{or} \ m{M}_1 \end{array}$	$\frac{p}{p_i}$	$\frac{\rho}{\rho \iota}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$rac{p_2}{p_1}$	$\frac{\rho_2}{\rho_1}$	$rac{T_2}{T_1}$	$rac{p_{\ell_2}}{p_{\ell_1}}$	$\frac{p_1}{p_{i_2}}$
33. 00 33. 20 33. 40 33. 60 33. 80	.6454 -8 .6188 -8 .5935 -8 .5692 -8 .5462 -8	$\begin{array}{cccc} .1412 & ^{-5} \\ .1370 & ^{-5} \\ .1330 & ^{-5} \\ .1291 & ^{-5} \\ .1253 & ^{-5} \end{array}$	$\begin{array}{cccc} .4570 & ^{-2} \\ .4516 & ^{-2} \\ .4462 & ^{-2} \\ .4409 & ^{-2} \\ .4358 & ^{-2} \end{array}$	32. 98 33. 18 33. 39 33. 59 33. 79	. 4920 -5 . 4774 -3 . 4634 -5 . 4499 -5 . 4368 -5	1837 +2 1893 +2 1950 +2 2009 +2 2069 +2	2. 4438858 2. 4439529 2. 4440188 2. 4440835 2. 4441471	121. 79 121. 84 121. 89 121. 94 121. 99	1. 737 1. 726 1. 716 1. 706 1. 695	. 3789 . 3788 . 3788 . 3788 . 3788	1270 1286 1301 1317 1333	5. 973 5. 973 5. 973 5. 974 5. 974	212. 7 215. 3 217. 9 220. 5 223. 1	. 9053 -5 . 8785 -5 . 8527 -5 . 8277 -5 . 8037 -5	.7129 -3 .7044 -3 .6960 -3 .6878 -3 .6796 -3
34. 00 34. 20 34. 40 34. 60 34. 80	. 5242 -8 . 5032 -8 . 4832 -8 . 4640 -8 . 4457 -8	$\begin{array}{c} .1217 & -5 \\ .1182 & -5 \\ .1148 & -5 \\ .1116 & -5 \\ .1084 & -5 \\ \end{array}$	$\begin{array}{cccc} .4307 & -2 \\ .4257 & -2 \\ .4208 & -2 \\ .4159 & -2 \\ .4112 & -2 \end{array}$	33. 99 34. 19 34. 39 34. 59 34. 79	$\begin{array}{rrrr} .4242 & ^{-5} \\ .4120 & ^{-5} \\ .4002 & ^{-5} \\ .3889 & ^{-5} \\ .3779 & ^{-5} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2. 4442095 2. 4442709 2. 4443312 2. 4443905 2. 4444488	122. 04 122. 09 122. 14 122. 19 122. 24	1. 685 1. 676 1. 666 1. 656 1. 647	. 3788 . 3788 . 3788 . 3788 . 3788	1349 1364 1380 1397 1413	5. 974 5. 975 5. 975 5. 975 5. 975	225. 7 228. 4 231. 0 233. 7 236. 4	$\begin{array}{rrrr} .7805 & -5 \\ .7581 & -5 \\ .7364 & -5 \\ .7155 & -5 \\ .6952 & -5 \end{array}$	. 6716 -3 . 6638 -3 . 6561 -3 . 6486 -3 . 6411 -3
35. 00 35. 20 35. 40 35. 69 35. 80	. 4283 -8 . 4116 -8 . 3957 -8 . 3804 -8 . 3658 -8	$\begin{array}{cccc} .1054 & -5 \\ .1024 & -5 \\ .9956 & -6 \\ .9680 & -6 \\ .9414 & -6 \end{array}$	$\begin{array}{cccc} .4065 & -2 \\ .4019 & -2 \\ .3974 & -2 \\ .3930 & -2 \\ .3886 & -2 \end{array}$	34. 99 35. 19 35. 39 35. 59 35. 79	. 3672 -5 . 3570 -5 . 3471 -5 . 3375 -5 . 3282 -5	2462 +2 2532 +2 2605 +2 2679 +2 2754 +2	2. 4445060 2. 4445623 2. 4446177 2. 4446721 2. 4447256	122. 28 122. 33 122. 37 122. 42 122. 47	1. 637 1. 628 1. 619 1. 610 1. 601	. 3788 . 3787 . 3787 . 3787 . 3787	1429 1445 1462 1478 1495	5. 976 5. 976 5. 976 5. 976 5. 977	239. 1 241. 9 244. 6 247. 4 250. 2	. 6757 -5 . 6568 -5 . 6385 -5 . 6210 -5 . 6039 -5	.6338 -3 .6267 -3 .6197 -3 .6126 -3 .6059 -3
36. 00 36. 20 36. 40 36. 60 36. 80	.3519 -8 .3386 -8 .3258 -9 .3136 -8 .3019 -8	$\begin{array}{c} .9156 & ^{-6} \\ .8907 & ^{-6} \\ .8666 & ^{-6} \\ .8433 & ^{-6} \\ .8207 & ^{-6} \end{array}$	$\begin{array}{ccccc} .3843 & ^{-2}\\ .3801 & ^{-2}\\ .3760 & ^{-2}\\ .3719 & ^{-2}\\ .3679 & ^{-2}\\ \end{array}$	35. 99 36. 19 36. 39 36. 59 36. 79	.3192 -5 .3106 -5 .3022 -5 .2941 -5 .2862 -5	2832 +2 2911 +2 2992 +2 3075 +2 3159 +2	2. 4447783 2. 4448300 2. 4448810 2. 4449311 2. 4449803	122. 51 122. 55 122. 60 122. 64 122. 68	1. 592 1. 583 1. 574 1. 566 1. 557	. 3787 . 3787 . 3787 . 3787 . 3787	1512 1529 1546 1563 1580	5. 977 5. 977 5. 977 5. 978 5. 978	252. 9 255. 8 258. 6 261. 4 264. 3	. 5874 -5 . 5714 -5 . 5560 -5 . 5410 -5 . 5265 -5	. 5991 -3 . 5925 -3 . 5860 -3 . 5797 -3 . 5734 -3
37. 00 37. 20 37. 40 37. 60 37. 80	. 2907 -8 . 2800 -8 . 2697 -8 . 2598 -8 . 2504 -8	$\begin{array}{cccc} .7988 & -6 \\ .7777 & -6 \\ .7572 & -6 \\ .7373 & -6 \\ .7181 & -6 \end{array}$	$\begin{array}{cccc} .3639 & -2 \\ .3600 & -2 \\ .3562 & -2 \\ .3524 & -2 \\ .3487 & -2 \end{array}$	36, 99 37, 19 37, 39 37, 59 37, 79	. 2786 -5 . 2712 -5 . 2641 -5 . 2572 -5 . 2504 -5	3246 +2 3334 +2 3424 +2 3516 +2 3611 +2	2. 4450288 2. 4450765 2. 4451235 2. 4451697 2. 4452152	122. 72 122. 77 122. 81 122. 85 122. 89	1. 549 1. 540 1. 532 1. 524 1. 516	. 3787 . 3787 . 3787 . 3787 . 3786	1597 1614 1632 1649 1667	5. 978 5. 978 5. 979 5. 979 5. 979	267. 1 270. 0 272. 9 275. 8 278. 8	. 5126 -5 . 4990 -5 . 4858 -5 . 4732 -5 . 4608 -5	. 5671 -3 . 5611 -3 . 5551 -3 . 5492 -3 . 5434 -3
38. 00 38. 20 38. 40 38. 60 38. 80	. 2414 -8 . 2327 -8 . 2244 -8 . 2164 -8 . 2087 -8	$\begin{array}{cccc} .6995 & -6 \\ .6814 & -6 \\ .6639 & -6 \\ .6469 & -6 \\ .6305 & -6 \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	37. 99 38. 19 38. 39 38. 59 38. 79	$\begin{array}{cccc} .2440 & ^{-5} \\ .2377 & ^{-5} \\ .2316 & ^{-5} \\ .2257 & ^{-5} \\ .2199 & ^{-5} \end{array}$	3706 +2 3805 +2 3905 +2 4007 +2 4112 +2	2. 4452599 2. 4453040 2. 4453474 2. 4453901 2. 4454321	122. 93 122. 97 123. 00 123. 04 123. 08	1. 508 1. 500 1. 492 1. 485 1. 477	. 3786 . 3786 . 3786 . 3786 . 3786	1685 1702 1720 1738 1756	5. 979 5. 980 5. 980 5. 980 5. 980	281. 7 284. 7 287. 7 290. 7 293. 7	. 4489 -5 . 4373 -5 . 4260 -5 . 4152 -5 . 4046 -5	. 5377 -3 . 5321 -3 . 5266 -3 . 5212 -3 . 5158 -3
39. 00 39. 20 39. 40 39. 60 39. 80	. 2013 -8 .1943 -8 .1875 -8 .1810 -8 .1748 -8	$\begin{array}{cccc} .6145 & -6 \\ .5991 & -6 \\ .5841 & -6 \\ .5695 & -6 \\ .5554 & -6 \end{array}$	$\begin{array}{ccccc} .3277 & -2 \\ .3243 & -2 \\ .3211 & -2 \\ .3178 & -2 \\ .3147 & -2 \\ \end{array}$	38. 99 39. 19 39. 39 39. 59 39. 79	. 2144 -5 . 2090 -5 . 2038 -5 . 1987 -3 . 1938 -5	4219 +2 4327 +2 4438 +2 4552 +2 4667 +2	2. 4454735 2. 4455143 2. 4455545 2. 4455940 2. 4456330	123. 12 123. 16 123. 19 123. 23 123. 27	1. 469 1. 462 1. 454 1. 447 1. 440	. 3786 . 3786 . 3786 . 3786 . 3786	1774 1793 1811 1829 1848	5. 980 5. 981 5. 981 5. 981 5. 981	296. 7 299. 7 302. 8 305. 9 309. 0	. 3944 -5 . 3845 -5 . 3749 -5 . 3655 -5 . 3565 -5	.5105 -3 .5053 -3 .5002 -3 .4952 -3 .4902 -3
40. 00 40. 20 40. 40 40. 60 40. 80	.1688 -8 .1639 -8 .1574 -8 .1521 -8 .1470 -8	$\begin{array}{ccccc} .5417 & -6 \\ .5284 & -6 \\ .5155 & -6 \\ .5029 & -6 \\ .4908 & -6 \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	39. 99 40. 19 40. 39 40. 59 40. 79	. 1890 -5 . 1844 -5 . 1799 -5 . 1755 -5 . 1713 -5	4785 +2 4906 +2 5028 +2 5154 +2 5281 +2	2. 4456714 2. 4457092 2. 4457464 2. 4457831 2. 4458193	123. 30 123. 34 123. 37 123. 41 123. 44	1. 433 1. 425 1. 418 1. 411 1. 404	. 3786 . 3786 . 3786 . 3786 . 3785	1867 1885 1904 1923 1942	5. 981 5. 982 5. 982 5. 982 5. 982	312. 1 315. 2 318. 3 321. 5 324. 6	$\begin{array}{rrrr} .3477 & ^{-5} \\ .3392 & ^{-5} \\ .3309 & ^{-5} \\ .3229 & ^{-5} \\ .3151 & ^{-5} \end{array}$	.4853 -3 $.4805 -3$ $.4757 -3$ $.4710 -3$ $.4665 -3$
41. 00 41. 20 41. 40 41. 60 41. 80	.1420 -8 .1373 -8 .1327 -8 .1283 -8 .1241 -8	$egin{array}{ccccc} .4789 & -6 \ .4675 & -6 \ .4563 & -6 \ .4455 & -6 \ .4349 & -6 \ \end{array}$	. 2966 -2 . 2937 -2 . 2909 -2 . 2881 -2 . 2854 -2	40. 99 41. 19 41. 39 41. 59 41. 79	.1671 -5 .1631 -5 .1592 -5 .1555 -5 .1518 -5	5412 +2 5544 +2 5680 +2 5818 +2 5959 +2	2. 4458549 2. 4458901 2. 4459247 2. 4459588 2. 4459924	123. 48 123. 51 123. 54 123. 58 123. 61	1. 398 1. 391 1. 384 1. 377 1. 371	. 3785 . 3785 . 3785 . 3785 . 3785	1961 1980 2000 2019 2038	5. 982 5. 982 5. 983 5. 983 5. 983	327. 8 331. 0 334. 2 337. 4 340. 7	. 3075 -5 . 3001 -5 . 2929 -5 . 2860 -5 . 2793 -5	. 4619 -3 . 4575 -3 . 4531 -3 . 4487 -3 . 4444 -3
42. 00 42. 20 42. 40 42. 60 42. 80	.1201 -8 .1161 -8 .1124 -8 .1087 -8 .1052 -8	$egin{array}{ccccccc} .4247 & -6 \\ .4148 & -6 \\ .4051 & -6 \\ .3957 & -6 \\ .3866 & -6 \\ \end{array}$	. 2827 -2 . 2800 -2 . 2774 -2 . 2748 -2 . 2722 -2	41. 99 42. 19 42. 39 42. 59 42. 79	.1482 -5 .1448 -5 .1414 -5 .1381 -5 .1349 -5	6102 +2 6248 +2 6397 +2 6549 +2 6704 +2	2. 4460256 2. 4460583 2. 4460905 2. 4461223 2. 4461536	123. 64 123. 67 123. 71 123. 74 123. 77	1. 364 1. 358 1. 351 1. 345 1. 339	. 3785 . 3785 . 3785 . 3785 . 3785	2058 2)78 2097 2117 2137	5. 983 5. 983 5. 983 5. 984 5. 984	343. 9 347. 2 350. 5 353. 8 357. 1	. 2727 -5 . 2663 -5 . 2602 -5 . 2541 -5 . 2483 -5	. 4402 -3 . 4360 -3 . 4319 -3 . 4279 -3 . 4239 -3
43. 00 43. 20 43. 40 43. 60 43. 80	. 1019 -8 . 9861 -9 . 9548 -9 . 9246 -9 . 8956 -9	$\begin{array}{rrrr} .3777 & -6 \\ .3691 & -6 \\ .3607 & -6 \\ .3525 & -6 \\ .3445 & -6 \end{array}$	. 2697 -2 . 2672 -2 . 2648 -2 . 2623 -2 . 2600 -2	42. 99 43. 19 43. 39 43. 59 43. 79	. 1318 -5 . 1288 -5 . 1259 -5 . 1230 -5 . 1203 -5	6861 +2 7022 +2 7186 +2 7352 +2 7522 +2	2. 4461845 2. 4462150 2. 4462451 2. 4462747 2. 4463039	123. 80 123. 83 123. 86 123. 89 123. 92	1. 333 1. 326 1. 320 1. 314 1. 308	. 3785 . 3785 . 3785 . 3785 . 3785	2157 2177 2197 2218 2238	5. 984 5. 984 5. 984 5. 984 5. 984	360. 5 363. 8 367. 2 370. 6 374. 0	. 2426 -5 . 2370 -5 . 2316 -5 . 2264 -5 . 2213 -5	. 4200 -3 . 4161 -3 . 4122 -3 . 4084 -3 . 4048 -3
44. 00 44. 20 44. 40 44. 60 44. 80	.8676 -9 .8405 -9 .8144 -9 .7893 -9 .7650 -9	$\begin{array}{ccccc} .3368 & ^{-6} \\ .3293 & ^{-6} \\ .3219 & ^{-6} \\ .3148 & ^{-6} \\ .3078 & ^{-6} \end{array}$	$\begin{array}{cccc} .2576 & -2 \\ .2553 & -2 \\ .2530 & -2 \\ .2507 & -2 \\ .2485 & -2 \\ \end{array}$	43. 99 44. 19 44. 39 44. 59 44. 79	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	7694 +2 7870 +2 8049 +2 8232 +2 8418 +2	2. 4463328 2. 4463612 2. 4463893 2. 4464170 2. 4464443	123. 95 123. 98 124. 01 124. 04 124. 07	1. 302 1. 296 1. 291 1. 285 1. 279	. 3785 . 3785 . 3785 . 3785 . 3784	2259 2279 2300 2321 2341	5. 985 5. 985 5. 985 5. 985 5. 985	377. 4 380. 8 384. 3 387. 7 391. 2	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	. 4011 -3 . 3975 -3 . 3939 -3 . 3904 -3 . 3869 -3
45. 00 45. 20 45. 40 45. 60 45. 80	$\begin{array}{cccc} .7416 & -9 \\ .7190 & -9 \\ .6971 & -9 \\ .6760 & -9 \\ .6557 & -9 \end{array}$	$ \begin{array}{rrrr} .3011 & ^{-6} \\ .2945 & ^{-6} \\ .2881 & ^{-6} \\ .2818 & ^{-6} \\ .2758 & ^{-6} $	$\begin{array}{cccc} .2463 & ^{-2} \\ .2441 & ^{-2} \\ .2420 & ^{-2} \\ .2399 & ^{-2} \\ .2378 & ^{-2} \end{array}$	44. 99 45. 19 45. 39 45. 59 45. 79	$\begin{array}{cccc} .1051 & ^{-5} \\ .1028 & ^{-5} \\ .1006 & ^{-5} \\ .9840 & ^{-6} \\ .9629 & ^{-6} \end{array}$	8606 +2 8798 +2 8995 +2 9194 +2 9396 +2	2. 4464713 2. 4464979 2. 4465241 2. 4465500 2. 4465756	124. 10 124. 12 124. 15 124. 18 124. 21	1. 273 1. 268 1. 262 1. 257 1. 251	. 3784 . 3784 . 3784 . 3784 . 3784	2362 2383 2405 2426 2447	5. 985 5. 985 5. 986 5. 986 5. 986	394. 7 398. 2 401. 7 405. 3 408. 8	. 1934 -5 . 1892 -5 . 1851 -5 . 1810 -5 . 1771 -5	. 3835 -3 . 3801 -3 . 3767 -3 . 3735 -3 . 3702 -3
46. 00 46. 20 46. 40 46. 60 46. 80	.6361 -9 .6171 -9 .5987 -9 .5810 -9 .5639 -9	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{ccccc} .2357 & -2 \\ .2337 & -2 \\ .2317 & -2 \\ .2297 & -2 \\ .2278 & -2 \\ \end{array}$	45. 99 46. 19 46. 39 46. 59 46. 79	.9422 -6 .9220 -6 .9023 -6 .8832 -6 .8646 -6	9603 +2 9813 +2 1003 +3 1024 +3 1047 +3	2. 4466009 2. 4466258 2. 4466504 2. 4466746 2. 4466986	124. 23 124. 26 124. 29 124. 31 124. 34	1, 246 1, 240 1, 235 1, 230 1, 224	.3784 .3784 .3784 .3784 .3784	2469 2490 2512 2533 2555	5. 986 5. 986 5. 986 5. 986 5. 986	412. 4 416. 0 419. 6 423. 2 426. 8	$\begin{array}{cccc} .1733 & -5 \\ .1696 & -5 \\ .1660 & -5 \\ .1625 & -5 \\ .1591 & -5 \\ \end{array}$	. 3670 -3 . 3638 -3 . 3607 -3 . 3576 -3 . 3546 -3
47. 00 47. 20 47. 40 47. 60 47. 80	.5474 -9 .5314 -9 .5159 -9 .5009 -9 .4865 -9	. 2424 -6 . 2373 -6 . 2323 -6 . 2275 -6 . 2228 -6	$\begin{array}{cccc} .2258 & -2 \\ .2239 & -2 \\ .2221 & -2 \\ .2202 & -2 \\ .2184 & -2 \\ \end{array}$	46. 99 47. 19 47. 39 47. 59 47. 79	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1069 +3 1092 +3 1115 +3 1139 +3 1163 +3	2. 4467223 2. 4467456 2. 4467687 2. 4467915 2. 4468140	124, 37 124, 39 124, 42 124, 44 124, 47	1, 219 1, 214 1, 209 1, 204 1, 199	. 3784 . 3784 . 3784 . 3784 . 3784	2577 2599 2621 2643 2666	5. 986 5. 987 5. 987 5. 987 5. 987	430. 5 434. 1 437. 8 441. 5 445. 2	.1557 -5 .1525 -5 .1493 -5 .1462 -5 .1431 -5	. 3516 -3 . 3486 -3 . 3457 -3 . 3427 -3 . 3399 -3
48. 00 48. 20 48. 40 48. 60 48. 80	.4725 -9 .4590 -9 .4459 -9 .4332 -9 .4210 -9	. 2182 -6 . 2137 -6 . 2094 -6 . 2051 -6 . 2009 -6	$\begin{array}{cccc} .2165 & ^{-2} \\ .2148 & ^{-2} \\ .2130 & ^{-2} \\ .2112 & ^{-2} \\ .2095 & ^{-2} \end{array}$	47, 99 48, 19 48, 39 48, 59 48, 79	$\begin{array}{cccc} .7620 & ^{-6} \\ .7464 & ^{-6} \\ .7312 & ^{-6} \\ .7163 & ^{-6} \\ .7018 & ^{-6} \end{array}$	1187 +3 1212 +3 1238 +3 1263 +3 1289 +3	2. 4468362 2. 4468581 2. 4468798 2. 4469012 2. 4469223	124. 49 124. 52 124. 54 124. 56 124. 59	1. 194 1. 189 1. 184 1. 179 1. 174	. 3784 . 3784 . 3784 . 3784 . 3784	2688 2710 2733 2756 2778	5. 987 5. 987 5. 987 5. 987 5. 987	448. 9 452. 7 456. 4 460. 2 464. 0	.1402 -5 .1373 -5 .1345 -5 .1318 -5 .1291 -5	. 3370 -3 . 3342 -3 . 3315 -3 . 3288 -3 . 3261 -3
49. 00 49. 20 49. 40 49. 60 49. 80	. 4091 -9 . 3976 -9 . 3865 -9 . 3758 -9 . 3653 -9	. 1969 -6 . 1929 -6 . 1890 -6 . 1853 -6 . 1816 -6	. 2078 -2 . 2061 -2 . 2045 -2 . 2028 -2 . 2012 -2	48. 99 49. 19 49. 39 49. 59 49. 79	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1316 +3 1343 +3 1370 +3 1398 +3 1427 +3	2. 4469432 2. 4469639 2. 4469842 2. 4470044 2. 4470243	124. 61 124. 64 124. 66 124. 68 124. 71	1. 169 1. 165 1. 160 1. 155 1. 151	. 3784 . 3784 . 3784 . 3784 . 3784	2801 2824 2847 2870 2893	5, 988 5, 988 5, 988 5, 988 5, 988	467. 8 471. 6 475. 5 479. 3 483. 2	$\begin{array}{cccc} .1265 & -5 \\ .1240 & -5 \\ .1215 & -5 \\ .1191 & -5 \\ .1167 & -5 \\ \end{array}$	$\begin{array}{ccccc} .3234 & -3 \\ .3208 & -3 \\ .3182 & -3 \\ .3157 & -3 \\ .3131 & -3 \\ \end{array}$
50. 00 51. 00 52. 00 53. 00 54. 00	.3553 -9 .3093 -9 .2701 -9 .2365 -9 .2075 -9	$\begin{array}{cccc} .1780 & -6 \\ .1612 & -6 \\ .1464 & -6 \\ .1331 & -6 \\ .1212 & -6 \\ \end{array}$	. 1996 -2 . 1919 -2 . 1846 -2 . 1777 -2 . 1712 -2	49, 99 50, 99 51, 99 52, 99 53, 99	$\begin{array}{cccc} .6217 & -6 \\ .5632 & -6 \\ .5113 & -6 \\ .4649 & -6 \\ .4235 & -6 \end{array}$	$\begin{array}{cccc} 1456 & {}^{+3}\\ 1607 & {}^{+3}\\ 1770 & {}^{+3}\\ 1947 & {}^{+3}\\ 2137 & {}^{+3} \end{array}$	2. 4470439 2. 4471388 2. 4472282 2. 4473126 2. 4473924	124. 73 124. 84 124. 95 125. 05 125. 15	1. 146 1. 124 1. 102 1. 081 1. 061	. 3783 . 3783 . 3783 . 3783 . 3783	2917 3034 3155 3277 3402	5. 988 5. 989 5. 989 5. 989 5. 990	487. 1 506. 7 526. 7 547. 1 567. 9	$\begin{array}{cccc} .1144 & -5 \\ .1036 & -5 \\ .9406 & -6 \\ .8553 & -6 \\ .7792 & -6 \\ \end{array}$	.3106 -3 .2985 -3 .2872 -3 .2765 -3 .2663 -3

TABLE II.—SUPERSONIC FLOW—Concluded

 $\gamma = 7/5$ 

							γι/ε	•							
$M \\  ext{or} \\ M_1$	$\frac{p}{p_t}$	$\frac{\rho}{\rho\iota}$	$\frac{T}{T_t}$	β	$\frac{q}{p_t}$	$\frac{A}{A_*}$	$\frac{V}{a_*}$	ν	μ	$M_2$	$\frac{p_2}{p^1}$	$\frac{\rho_2}{\rho_1}$	$\frac{T_2}{T_1}$	$\frac{p_{t_2}}{p_{t_1}}$	$\frac{p_1}{p_{t_2}}$
55. 00 56. 00 57. 00 58. 00 59. 00	. 1826 -9 . 1609 -9 . 1422 -9 . 1259 -9 . 1118 -9	$\begin{array}{ccccc} .1106 & -6 \\ .1011 & -6 \\ .9256 & -7 \\ .8485 & -7 \\ .7791 & -7 \end{array}$	$\begin{array}{ccccc} .1650 & ^{-2} \\ .1592 & ^{-2} \\ .1537 & ^{-2} \\ .1484 & ^{-2} \\ .1434 & ^{-2} \end{array}$	54. 99 55. 99 56. 99 57. 99 58. 99	$\begin{array}{cccc} .3866 & -6 \\ .3533 & -6 \\ .3235 & -6 \\ .2965 & -6 \\ .2723 & -6 \end{array}$	2341 +3 2562 +3 2798 +3 3052 +3 3324 +3	2. 4474679 2. 4475394 2. 4476071 2. 4476714 2. 4477325	125. 25 125. 34 125. 43 125. 52 125. 60	1. 042 1. 023 1. 005 . 9879 . 9712	. 3783 . 3783 . 3783 . 3783 . 3782	3529 3659 3790 3925 4061	5. 990 5. 990 5. 991 5. 991 5. 991	589. 1 610. 7 632. 7 655. 1 677. 8	.7111 -6 .6499 -6 .5950 -6 .5455 -6 .5009 -6	$\begin{array}{ccccc} .2567 & -3 \\ .2476 & -3 \\ .2390 & -3 \\ .2308 & -3 \\ .2231 & -3 \end{array}$
60. 00 61. 00 62. 00 63. 00 64. 00	$\begin{array}{cccc} .9937 & ^{-10} \\ .8852 & ^{-10} \\ .7900 & ^{-10} \\ .7065 & ^{-10} \\ .6328 & ^{-10} \end{array}$	.7165 -7 .6596 -7 .6082 -7 .5615 -7 .5190 -7	$\begin{array}{c cccc} .1387 & -2 \\ .1342 & -2 \\ .1299 & -2 \\ .1258 & -2 \\ .1219 & -2 \\ \end{array}$	59. 99 60. 99 61. 99 62. 99 63. 99	$\begin{array}{cccc} .2504 & -6 \\ .2306 & -6 \\ .2126 & -6 \\ .1963 & -6 \\ .1814 & -6 \\ \end{array}$	3615 +3 3926 +3 4258 +3 4612 +3 4990 +3	2. 4477905 2. 4478457 2. 4478982 2. 4479483 2. 4479961	125. 68 125. 76 125. 84 125. 91 125. 98	. 9550 . 9393 . 9241 . 9095 . 8953	. 3782 . 3782 . 3782 . 3782 . 3782	4200 4341 4485 4630 4779	5. 992 5. 992 5. 992 5. 993 5. 993	700. 9 724. 5 748. 4 772. 7 797. 4	. 4606 -6 . 4241 -6 . 3911 -6 . 3611 -6 . 3338 -6	. 2157 -3 . 2037 -3 . 2020 -3 . 1957 -3 . 1896 -3
65. 00 66. 00 67. 00 68. 00 69. 00	.5678 -10 .5103 -10 .4594 -10 .4141 -10 .3740 -10	. 4803 -7 . 4451 -7 . 4129 -7 . 3834 -7 . 3565 -7	$\begin{array}{cccc} .1182 & -2 \\ .1147 & -2 \\ .1113 & -2 \\ .1080 & -2 \\ .1049 & -2 \end{array}$	64, 99 65, 99 66, 99 67, 99 68, 99	.1679 -6 .1556 -6 .1444 -6 .1340 -6 .1246 -6	5391 +3 5818 +3 6271 +3 6754 +3 7264 +3	2. 4480416 2. 4480851 2. 4481267 2. 4481665 2. 4482045	126. 05 126. 12 126. 18 126. 24 126. 30	. 8815 . 8682 . 8552 . 8426 . 8304	. 3782 . 3782 . 3782 . 3782 . 3782	4929 5032 5237 5395 5554	5. 993 5. 993 5. 993 5. 994 5. 994	822. 5 847. 9 873. 8 900. 1 926. 7	$\begin{array}{cccc} .3039 & -6 \\ .2863 & -6 \\ .2655 & -6 \\ .2466 & -6 \\ .2293 & -6 \\ \end{array}$	. 1838 -3 . 1783 -3 . 1730 -3 . 1679 -3 . 1631 -3
70.00 71.00 72.00 73.00 74.00	.3382 -10 .3062 -10 .2777 -10 .2522 -10 .2293 -10	. 3318 -7 . 3091 -7 . 2882 -7 . 2690 -7 . 2513 -7	$\begin{array}{cccc} .1019 & -2 \\ .9909 & -3 \\ .9536 & -3 \\ .9374 & -3 \\ .9122 & -3 \end{array}$	69. 99 70. 99 71. 99 72. 99 73. 99	.1160 -6 .1081 -6 .1003 -6 .9406 -7 .8789 -7	7804 +3 8378 +3 8984 +3 9625 +3 1030 +4	2. 4482410 2. 4482759 2. 4483093 2. 4483414 2. 4483722	126, 36 126, 42 126, 48 126, 53 126, 59	. 8185 . 8070 . 7958 . 7849 . 7742	. 3782 . 3782 . 3782 . 3781 . 3781	5717 5881 6048 6217 6389	5. 994 5. 994 5. 994 5. 994 5. 995	953. 7 981. 1 1009 1037 1066	.2134 -6 .1988 -6 .1854 -6 .1730 -6 .1617 -6	. 1585 -3 . 1540 -3 . 1498 -3 . 1457 -3 . 1418 -3
75. 00 76. 00 77. 00 78. 00 79. 00	$\begin{array}{ccccc} .2088 & -10 \\ .1903 & -10 \\ .1737 & -10 \\ .1587 & -10 \\ .1451 & -10 \\ \end{array}$	. 2351 -7 . 2200 -7 . 2061 -7 . 1932 -7 . 1813 -7	.8881 -3 .8649 -3 .8426 -3 .8212 -3 .8005 -3	74. 99 75. 99 76. 99 77. 99 78. 99	. 8220 -7 . 7693 -7 . 7207 -7 . 6757 -7 . 6341 -7	1102 +4 1177 +4 1256 +4 1340 +4 1428 +4	2. 4484018 2. 4484302 2. 4484576 2. 4484838 2. 4485091	126. 64 126. 69 126. 74 126. 78 126. 83	. 7639 . 7539 . 7441 . 7345 . 7253	. 3781 . 3781 . 3781 . 3781 . 3781	6562 6739 6917 7098 7281	5. 995 5. 995 5. 995 5. 995 5. 995	1095 1124 1154 1184 1215	. 1512 -6 . 1415 -6 . 1326 -6 . 1243 -6 . 1166 -6	. 1381 -3 . 1345 -3 . 1310 -3 . 1276 -3 . 1244 -3
80. 00 81. 00 82. 00 83. 00 84. 00	$\begin{array}{cccc} .1329 & -10 \\ .1219 & -10 \\ .1118 & -10 \\ .1027 & -10 \\ .9448 & -11 \\ \end{array}$	. 1703 -7 . 1600 -7 . 1505 -7 . 1417 -7 . 1334 -7	. 7806 -3 . 7615 -3 . 7431 -3 . 7253 -3 . 7081 -3	79, 99 80, 99 81, 99 82, 99 83, 99	. 5264 -7 . 4954 -7	1521 ++ 1618 +4 1720 ++ 1828 ++ 1940 ++	2. 4485335 2. 4485569 2. 4485795 2. 4486013 2. 4486223	126. 88 126. 92 126. 96 127. 00 127. 05	. 7162 . 7074 . 6937 . 6903 . 6821	.3781 .3781 .3781 .3781 .3781	7467 7654 7845 8037 8232	5. 995 5. 995 5. 996 5. 996 5. 996	1245 1277 1308 1341 1373	. 1095 -6 . 1030 -6 . 9682 -7 . 9113 -7 . 8585 -7	. 1214 -3 . 1184 -3 . 1155 -3 . 1127 -3 . 1101 -3
85. 00 86. 00 87. 00 88. 00 89. 00	. 8697 -11 . 8014 -11 . 7391 -11 . 6823 -11 . 6305 -11	. 1258 -7 . 1186 -7 . 1120 -7 . 1058 -7 . 9995 -8	$\begin{array}{cccc} .6916 & -3 \\ .6756 & -3 \\ .6602 & -3 \\ .6452 & -3 \\ .6308 & -3 \\ \end{array}$	84. 99 85. 99 86. 99 87. 99 88. 99	. 4149 -7 . 3916 -7 . 3699 -7	2059 +4 2182 +4 2312 +4 2448 +4 2590 +4	2. 4486426 2. 4486622 2. 4486811 2. 4486994 2. 4487170	127. 09 127. 12 127. 16 127. 20 127. 24	. 6741 . 6662 . 6586 . 6511 . 6438	. 3781 . 3781 . 3781 . 3781 . 3781	8429 8529 8830 9035 9241	5. 996 5. 996 5. 996 5. 996 5. 996	1406 1439 1473 1507 1541	. 8092 -7 . 7632 -7 . 7204 -7 . 6804 -7 . 6431 -7	. 1075 -3 . 1050 -3 . 1026 -3 . 1003 -3 . 9805 -4
90. 00 91, 00 92. 00 93. 00 94. 00	. 5831 -11 . 5397 -11 . 5000 -11 . 4636 -11 . 4302 -11	. 9452 -8 . 8944 -8 . 8469 -8 . 8023 -8 . 7606 -8	$\begin{array}{cccc} .6169 & ^{-3} \\ .6034 & ^{-3} \\ .5904 & ^{-3} \\ .5778 & ^{-3} \\ .5656 & ^{-3} \end{array}$	89. 99 90. 99 91. 99 92. 99 93. 99	. 3129 -7 . 2962 -7 . 2807 -7	2739 +4 2894 +4 3057 +4 3226 +4 3403 +4	2. 4487341 2. 4487506 2. 4487666 2. 4487820 2. 4487970	127. 27 127. 31 127. 34 127. 38 127. 41	. 6366 . 6296 . 6228 . 6160 . 6095	. 3781 . 3781 . 3781 . 3781 . 3781	9450 9661 9875 1009 +1 1031 +1	5. 996 5. 996 5. 997 5. 997 5. 997	1576 1611 1647 1683 1719	.6032 -7 .5755 -7 .5450 -7 .5163 -7 .4894 -7	. 9588 -4 . 9378 -4 . 9175 -4 . 8978 -4 . 8790 -4
95.00 96.00 97.00 98.00 99.00	. 3995 -11 . 3712 -11 . 3453 -11 . 3214 -11 . 2993 -11	.7214 -9 .6846 -8 .6501 -9 .6176 -8 .5870 -8	$\begin{array}{cccc} .5537 & ^{-3} \\ .5422 & ^{-3} \\ .5311 & ^{-3} \\ .5204 & ^{-3} \\ .5099 & ^{-3} \\ \end{array}$	94. 99 95. 99 96. 99 97. 99 98. 99	. 2395 -7 . 2274 -7 . 2161 -7	3588 +4 3781 +4 3982 +4 4191 +4 4410 +4	2. 4488115 2. 4488255 2. 4488392 2. 4488524 2. 4488652	127. 44 127. 47 127. 50 127. 53 127. 56	. 6031 . 5968 . 5907 . 5847 . 5787	. 3781 . 3781 . 3781 . 3781 . 3781	1053 +1 1075 +1 1098 +1 1121 +1 1143 +1	5. 997 5. 997 5. 997 5. 997 5. 997	1756 1793 1831 1869 1907	.4642 - 7 $.4405 - 7$ $.4183 - 7$ $.3974 - 7$ $.3778 - 7$	. 8605 -4 . 8427 -4 . 8254 -4 . 8087 -4 . 7923 -4
100.00	. 2790 -11	.5583 -8	. 4998 -3	100.00	. 1953 -7	4637 +4	2. 4488776	127. 59	. 5730	. 3781	1167 +1	5. 997	1945	. 3593 -7	. 7765 -4

#### NOTATIONS FOR TABLES I AND II

M or  $M_1$  local Mach number or Mach number upstream of a normal shock wave

 $\frac{p}{p_t}$ ratio of static pressure to total pressure

ratio of static density to total density

ratio of static temperature to total temperature

 $\sqrt{M^2-1}$ 

 $\frac{\frac{\rho}{\rho_t}}{T} \frac{T}{T_t}$   $\beta \frac{q}{p_t}$   $\frac{A}{A_*}$ ratio of dynamic pressure,  $\frac{1}{2} \rho V^2$ , to total pressure

ratio of local cross-sectional area of an isentropic stream tube to cross-sectional area at the point where M=1

ratio of local speed to speed of sound at the point where M=1

Prandtl-Meyer angle (angle through which a supersonic stream is turned to expand from M=1to M>1), deg

Mach angle,  $\sin^{-1}\frac{1}{M}$ , deg μ

 $M_2$ Mach number downstream of a normal shock wave

static pressure ratio across a normal shock wave  $p_1$ 

static density ratio across a normal shock wave

static temperature ratio across a normal shock wave

 $p_{t_2}$ total pressure ratio across a normal shock wave  $p_{t_1}$ 

 $p_1$ ratio of static pressure upstream of a normal shock wave to total pressure downstream

#### **CHARTS**

The charts that follow present numerical values of certain physical quantities that are functions of two variables and hence are cumbersome to tabulate. These charts are designed to provide accuracy to three significant figures.

Charts 1 through 8 and chart 25 are for a perfect gas. The values presented in charts 1 through 4 and chart 25 were calculated for a ratio of specific heats of 7/5. The values presented in charts 5 through 8 were taken from references 6 and 14 and are for a ratio of specific heats of 1.405.

Charts 9 through 24 provide correction factors to account for the effects of caloric imperfections on the quantities tabulated in tables I and II and plotted in charts 2, 3, and 4.

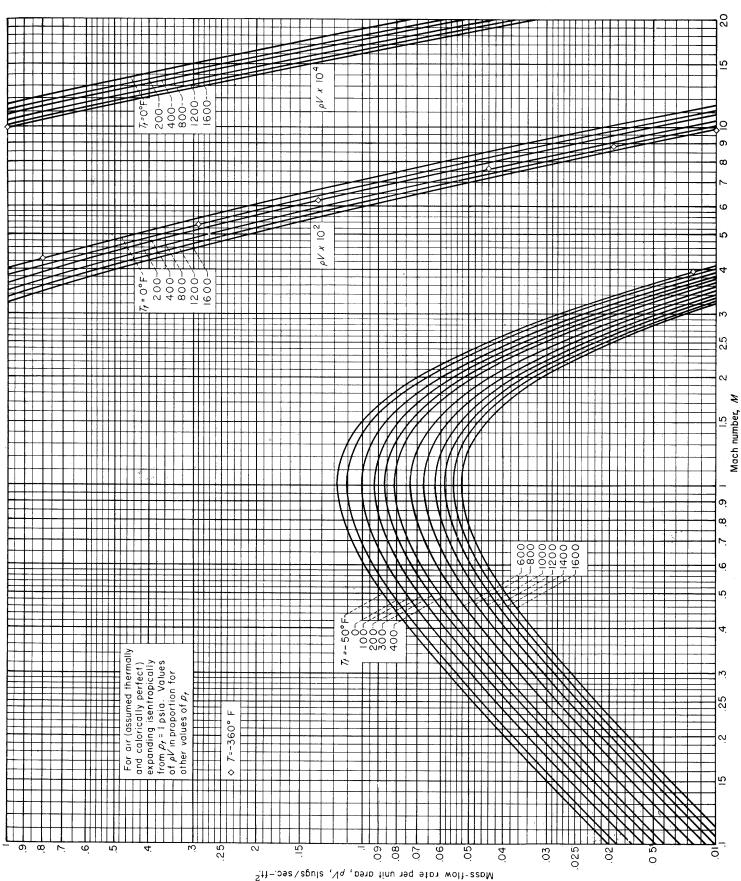
On many charts, points corresponding to static temperatures of 5000° R and 100°R (-360° F) have been indicated. These temperatures represent very approximately the limits of validity of the charts. Exact limits cannot be stated simply as they depend on pressure as well as temperature. At temperatures near 5000° R dissociation effects, which were neglected in the calculations, can be significant at high altitudes though perhaps not at sea level. At temperatures less than about 100° R, air may condense at the pressures encountered in many wind tunnels.

On the Reynolds number chart (chart 25), points corresponding to a static temperature of 180° R (-280° F) also are indicated since this is the lowest temperature for which experimental viscosity data have been obtained. At temperatures much lower than -280° F, Sutherland's equation (A2) may significantly underestimate the true viscosity.

The contents of the charts are as follows:	Page	20. Effect of caloric imperfections on the total-pressure ratio across a normal shock wave	59
1. Variation of mass-flow rate per unit area with Mach number for various total temperatures. Perfect gas, $\gamma = 7/5$	41	21. Effect of caloric imperfections on the variation with flow-deflection angle of the shock-wave angle for a weak oblique shock wave	60
<ol> <li>Variation of shock-wave angle with flow-deflection angle for various upstream Mach numbers. Perfect gas, γ=7/5.</li> <li>Variation of pressure coefficient across shock waves with</li> </ol>	42	22. Effect of caloric imperfections on the variation with flow-deflection angle of the Mach number downstream of a weak oblique shock wave	64
<ul> <li>flow-deflection angle for various upstream Mach numbers.</li> <li>Perfect gas, γ=7/5</li></ul>	44	23. Effect of caloric imperfections on the variation with flow-deflection angle of the pressure coefficient across a weak oblique shock wave	60
Perfect gas, $\gamma = 7/5$	46	24. Effect of caloric imperfections on the Prandtl-Meyer angle	68
5. Variation of shock-wave angle with cone semivertex angle for various upstream Mach numbers. Perfect gas, $\gamma =$		25. Variation of Reynolds number per unit length with Mach number for various total temperatures. Perfect gas,	
1.405	48	$\gamma = 7/5$	69

Char	t
6.	Variation of surface pressure coefficient with cone semivertex angle for various upstream Mach numbers. Perfect gas, $\gamma = 1.405$
7.	Variation of Mach number at the surface of a cone with cone semivertex angle for various upstream Mach numbers. Perfect gas, $\gamma = 1.405$
8.	Variation of the initial slope of the normal-force curve with upstream Mach number for various cone semivertex angles. Perfect gas, $\gamma = 1.405$
9.	Effect of caloric imperfections on the ratio of local speed to speed of sound at the point where $M=1$
10.	Effect of caloric imperfections on the ratio of static temperature to total temperature
11.	Effect of caloric imperfections on the ratio of static density to total density
12.	Effect of caloric imperfections on the ratio of static pressure to total pressure
13.	Effect of caloric imperfections on the ratio of dynamic pressure to total pressure
14.	Effect of caloric imperfections on the ratio of local cross-sectional area of a stream tube to the cross-sectional area at the point where $M=1$ .
15.	Effect of caloric imperfections on the static-temperature ratio across a normal shock wave
16.	Effect of caloric imperfections on the static-density ratio across a normal shock wave
17.	Effect of caloric imperfections on the ratio of static pressure upstream of a normal shock wave to total pressure downstream
18.	Effect of caloric imperfections on the static-pressure ratio across a normal shock wave
19.	Effect of caloric imperfections on the Mach number downstream of a normal shock wave-
20.	Effect of caloric imperfections on the total-pressure ratio across a normal shock wave
21.	Effect of caloric imperfections on the variation with flow-deflection angle of the shock-wave angle for a weak oblique shock wave
22.	Effect of caloric imperfections on the variation with flow-deflection angle of the Mach number downstream of a weak oblique shock wave
<b>2</b> 3.	Effect of caloric imperfections on the variation with flow-





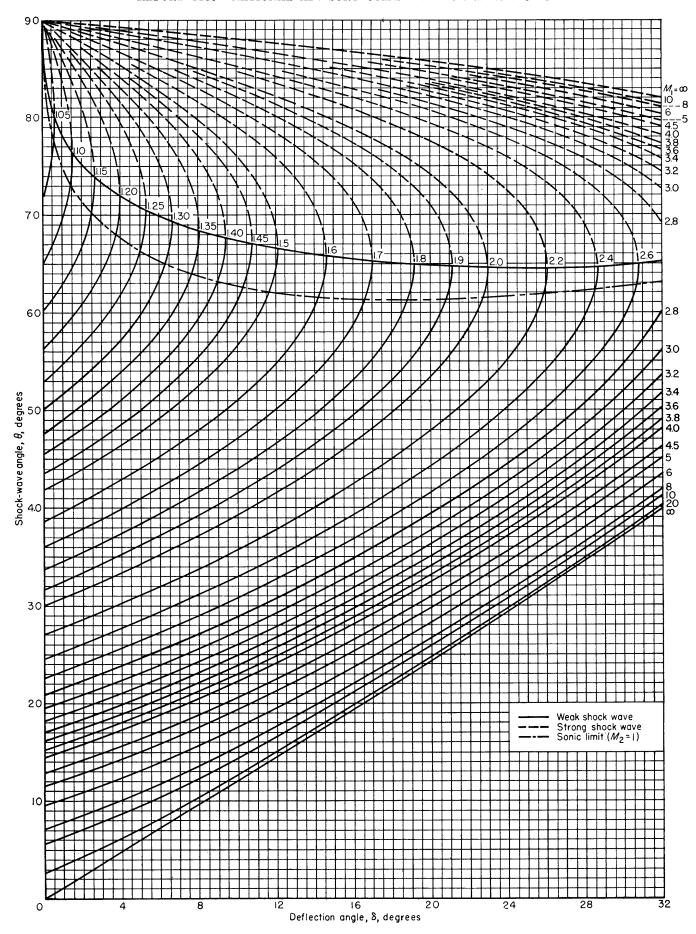


Chart 2.—Variation of shock-wave angle with flow-deflection angle for various upstream Mach numbers. Perfect gas,  $\gamma = \%$ .

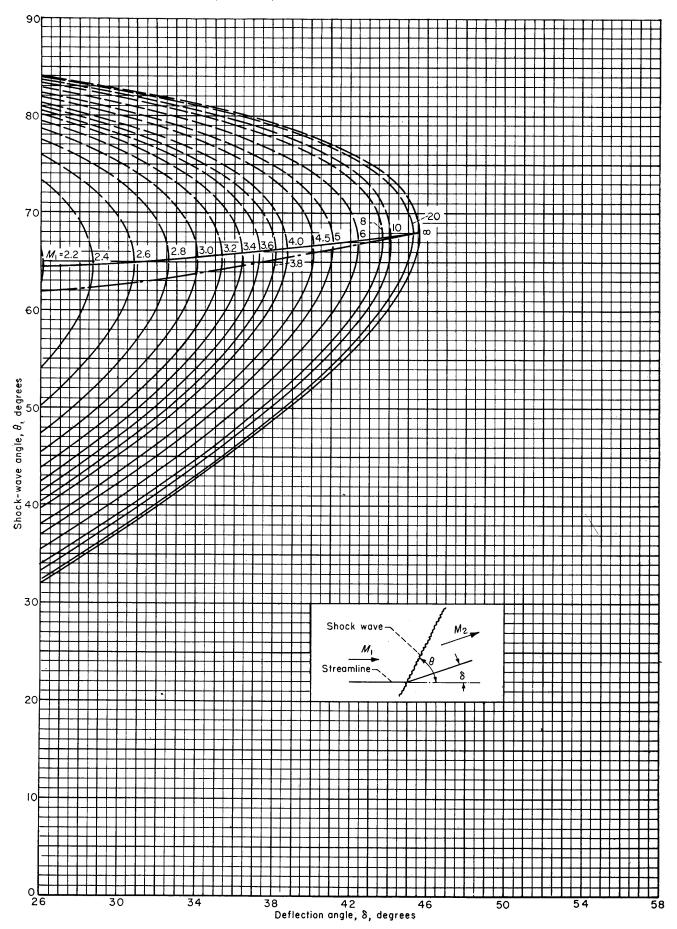


CHART 2.—Concluded

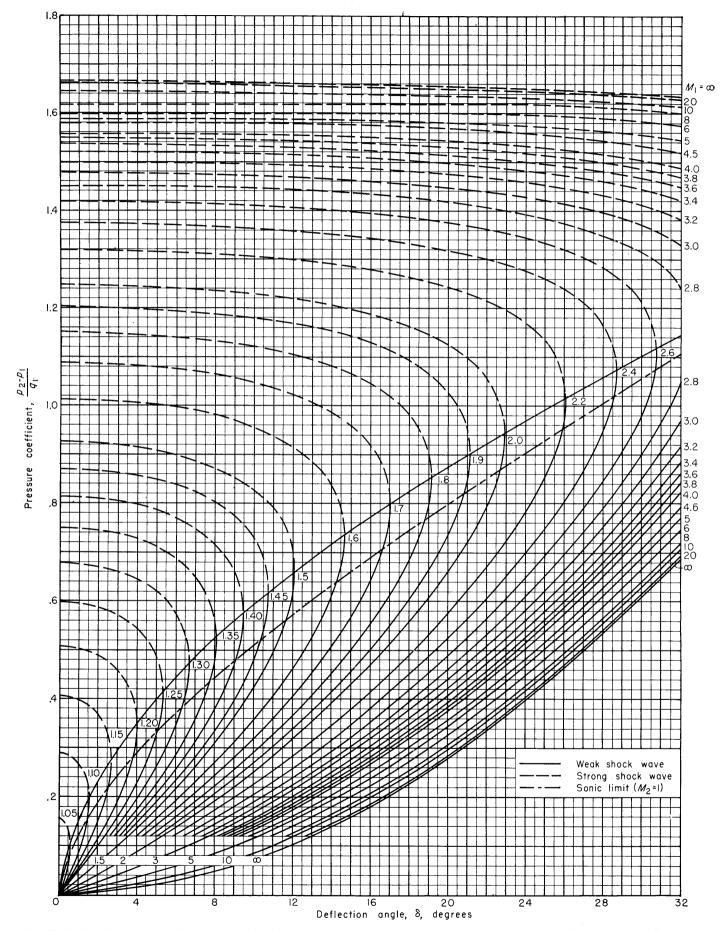


Chart 3.—Variation of pressure coefficient across shock waves with flow-deflection angle for various upstream Mach numbers. Perfect gas,  $\gamma = \frac{1}{3}$ 

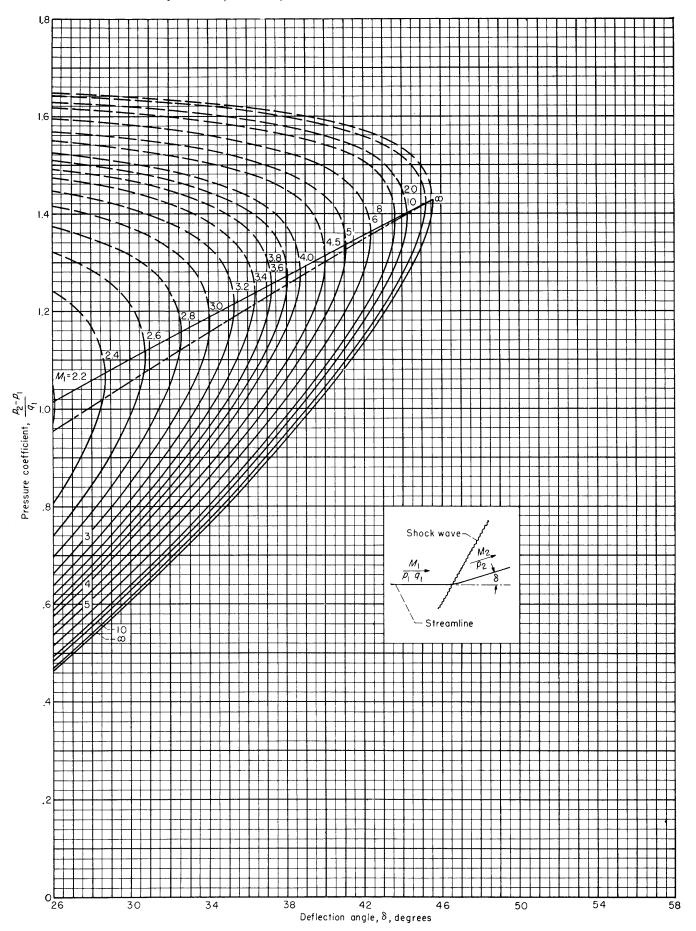


CHART 3.—Concluded

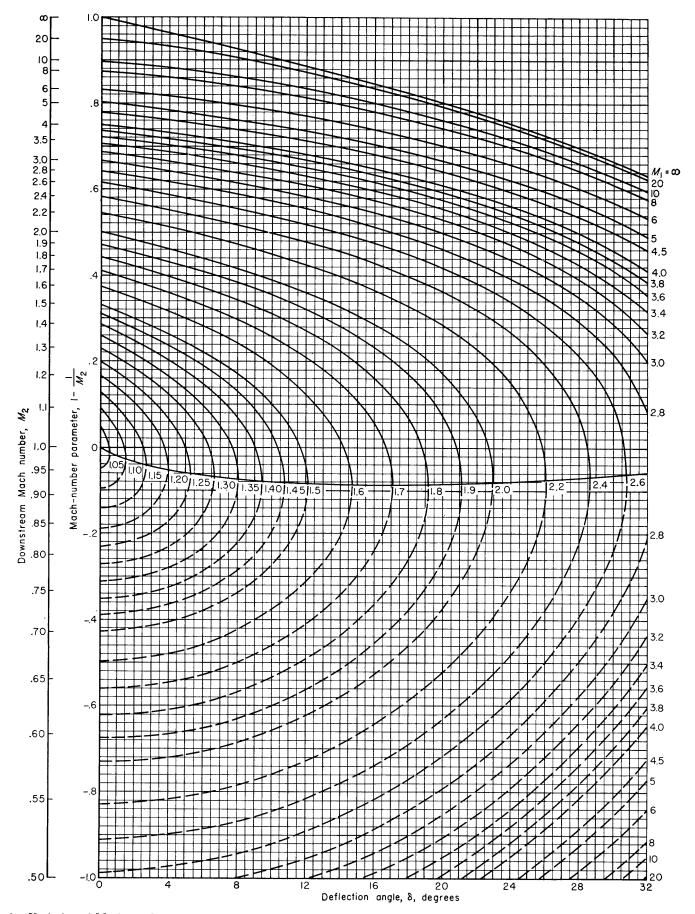


Chart 4.—Variation of Mach number downstream of a shock wave with flow-deflection angle for various upstream Mach numbers. Perfect gas,  $\gamma = \frac{\gamma}{5}$ .

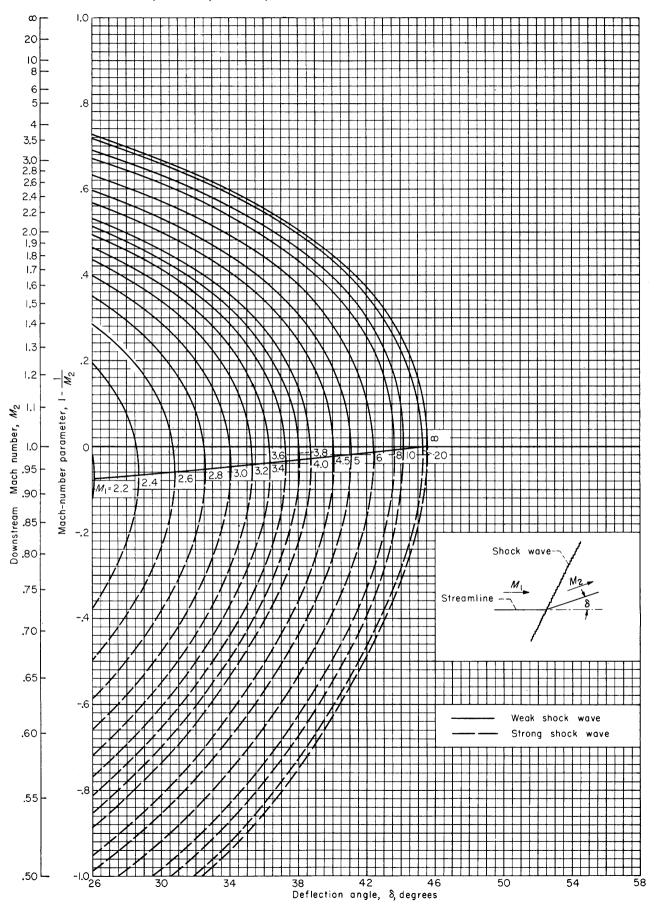


CHART 4.—Concluded

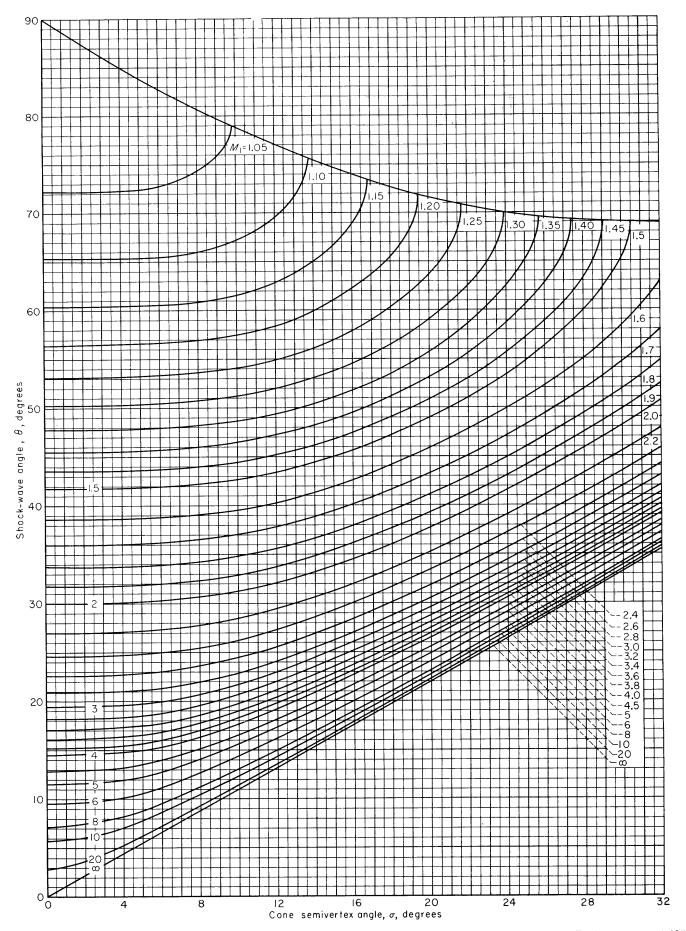


Chart 5.—Variation of shock-wave angle with cone semivertex angle for various upstream Mach numbers. Perfect gas,  $\gamma = 1.405$ .

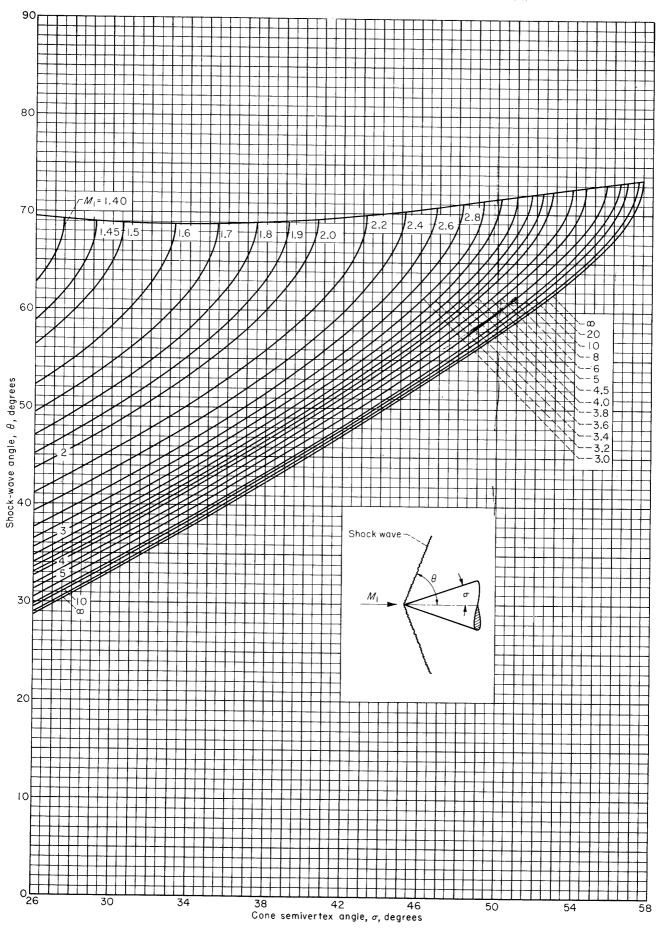


CHART 5.—Concluded

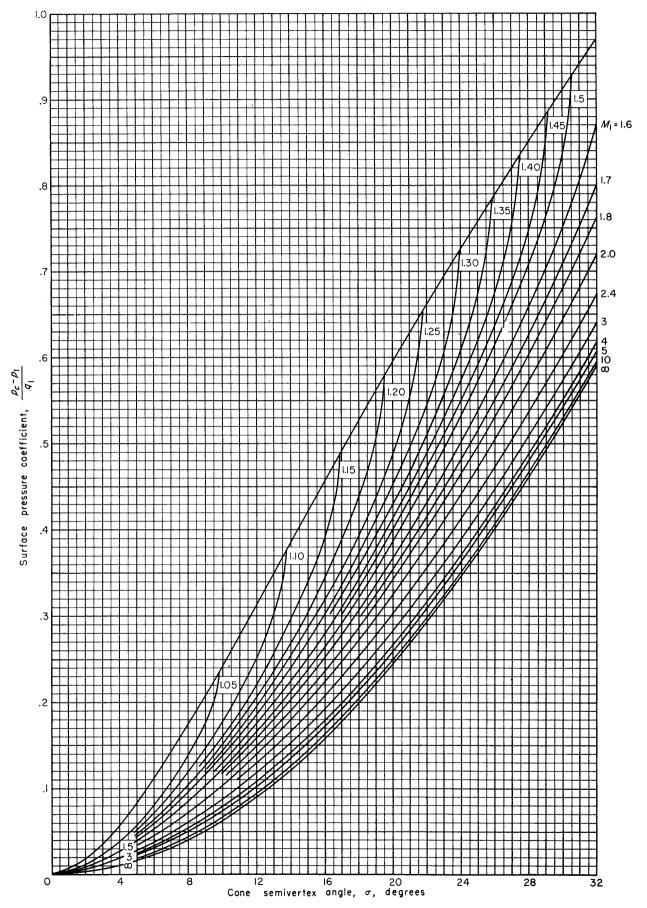
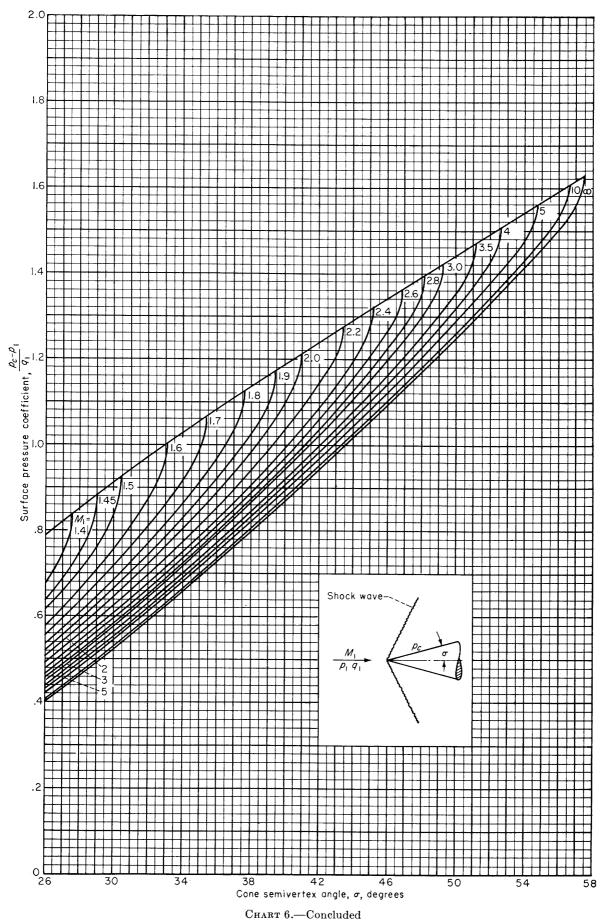


Chart 6.—Variation of surface pressure coefficient with cone semivertex angle for various upstream Mach numbers. Perfect gas,  $\gamma = 1.405$ .



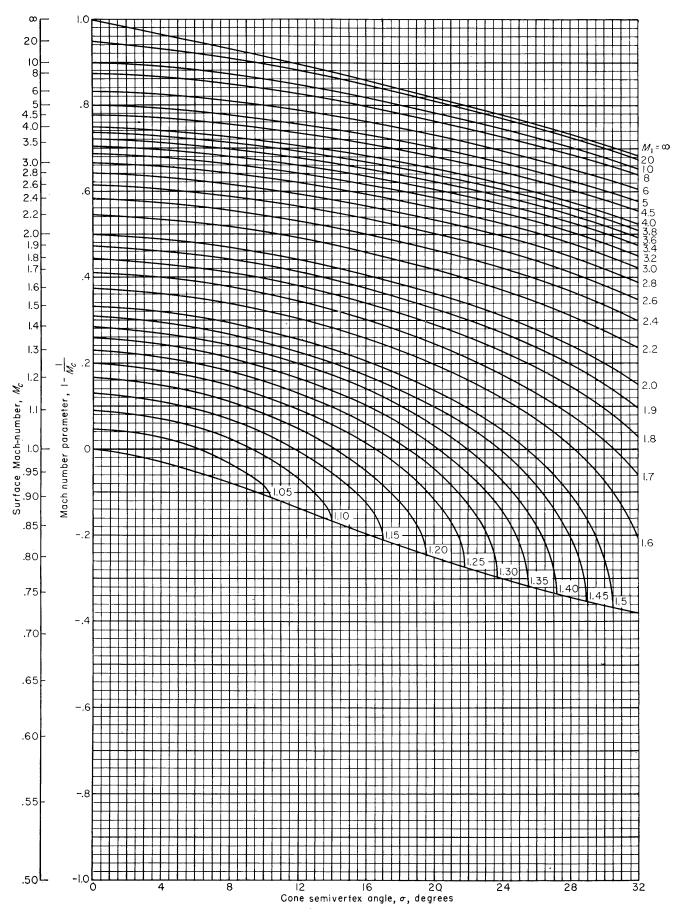


Chart 7.—Variation of Mach number at the surface of a cone with cone semivertex angle for various upstream Mach numbers. Perfect gas,  $\gamma = 1.405$ .

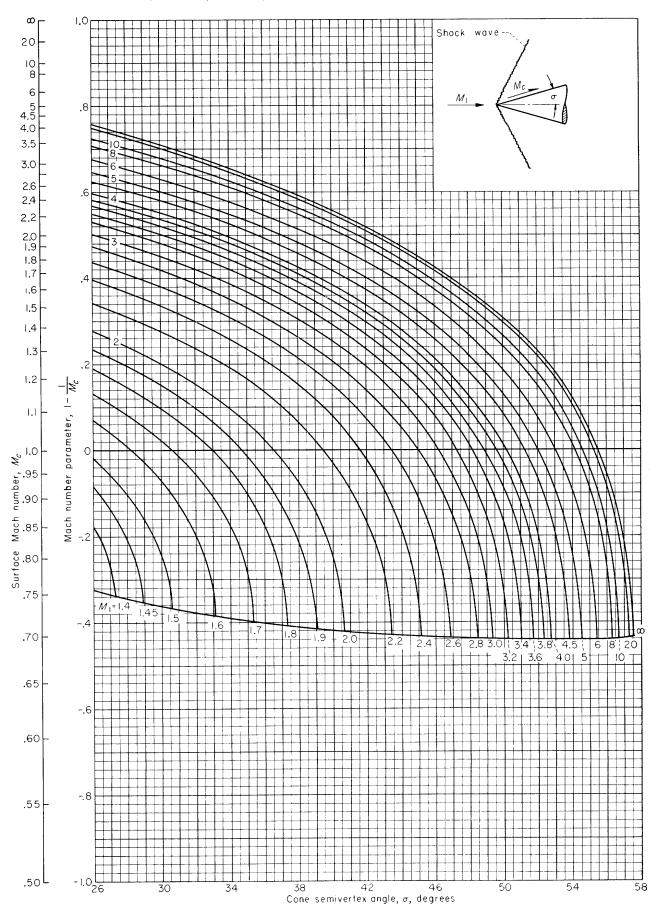


Chart 7.—Concluded

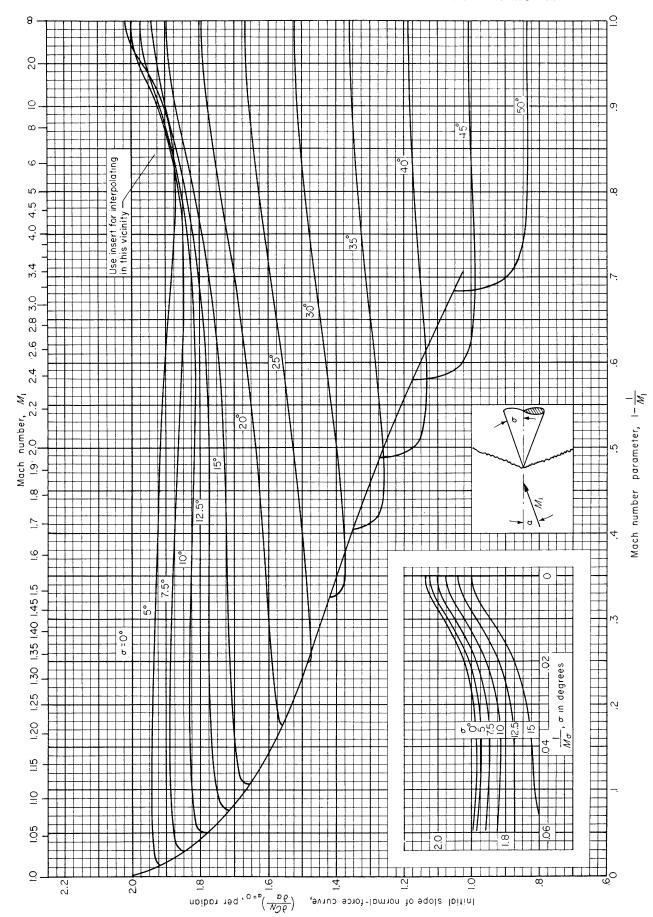


CHART 8.—Variation of the initial slope of the normal-force curve with upstream Mach number for various cone semivertex angles. Perfect gas,

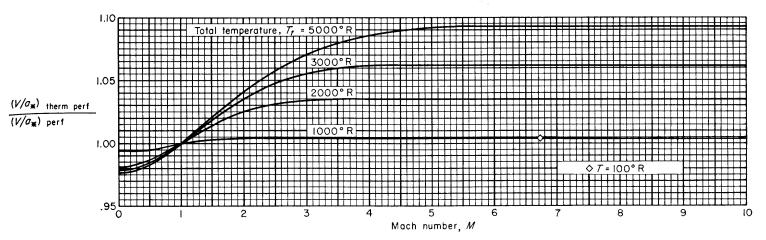


Chart 9.—Effect of caloric imperfections on the ratio of local speed to speed of sound at the point where M=1.

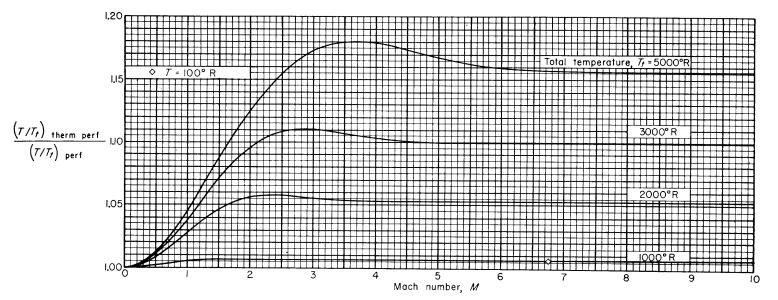


CHART 10.—Effect of caloric imperfections on the ratio of static temperature to total temperature

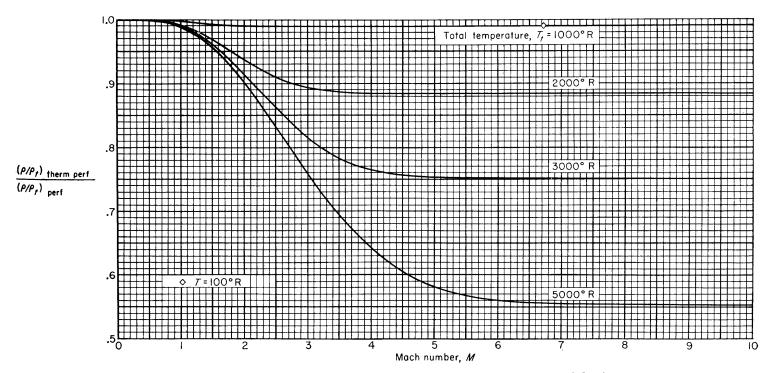


Chart 11.—Effect of caloric imperfections on the ratio of static density to total density.

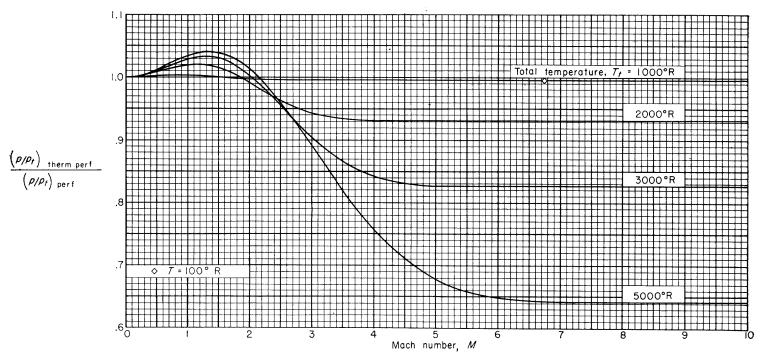


Chart 12.—Effect of caloric imperfections on the ratio of static pressure to total pressure.

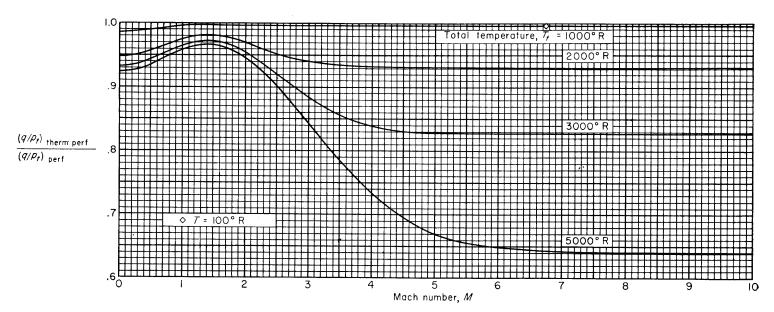


Chart 13.—Effect of caloric imperfections on the ratio of dynamic pressure to total pressure.

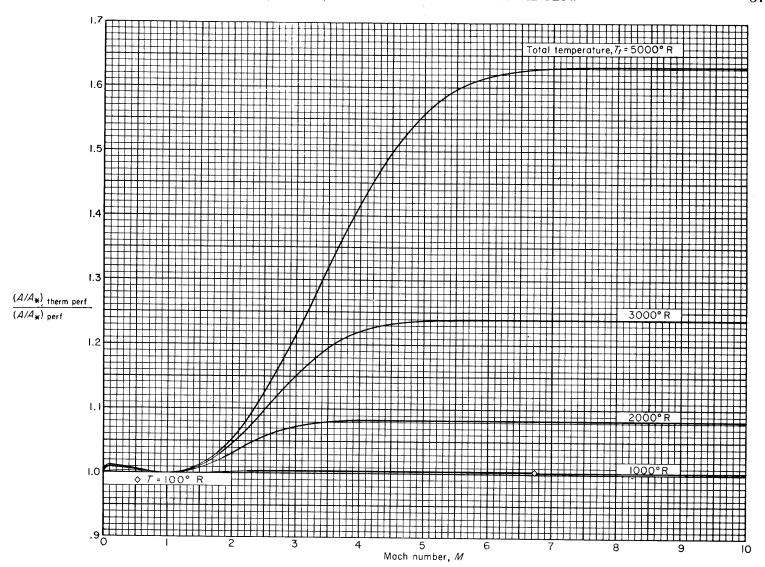


Chart 14.—Effect of caloric imperfections on the ratio of local cross-sectional area of a stream tube to the cross-sectional area at the point where M=1.

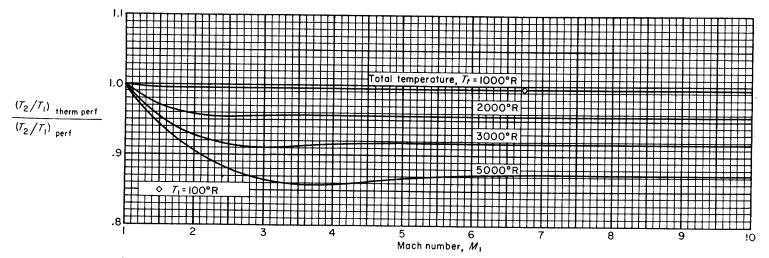


Chart 15.—Effect of caloric imperfections on the static-temperature ratio across a normal shock wave.

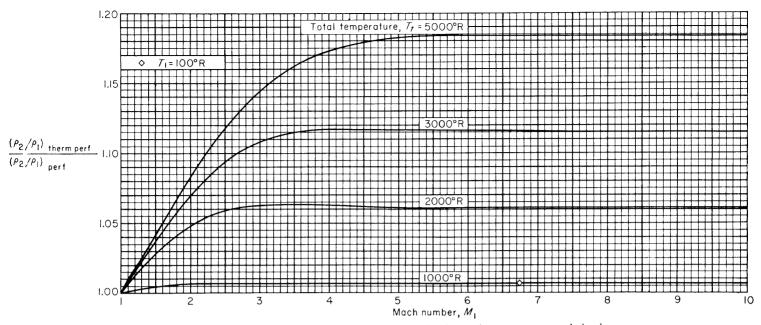


Chart 16.—Effect of caloric imperfections on the static-density ratio across a normal shock wave.

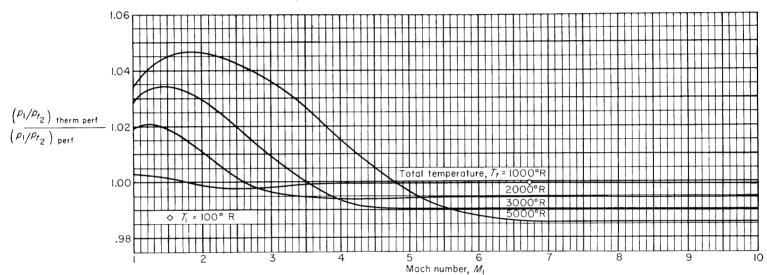


Chart 17.—Effect of caloric imperfections on the ratio of static pressure upstream of a normal shock wave to total pressure downstream.

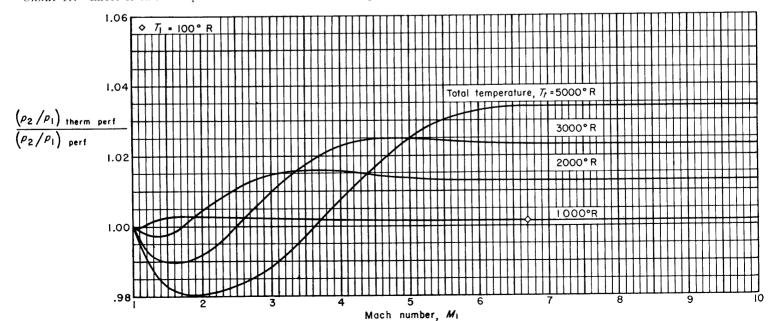


CHART 18.—Effect of caloric imperfections on the static-pressure ratio across a normal shock wave.

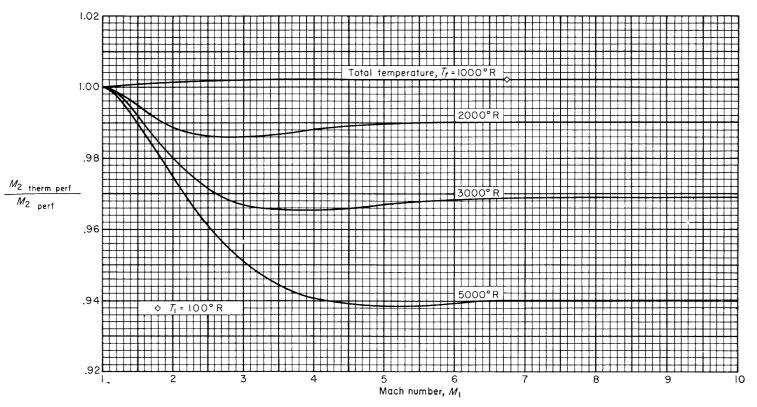


Chart 19.—Effect of caloric imperfections on the Mach number downstream of a normal shock wave.

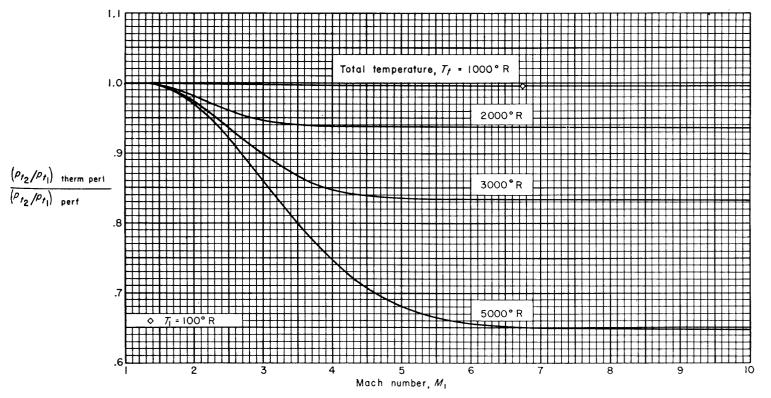


Chart 20.—Effect of caloric imperfections on the total-pressure ratio across a normal shock wave.

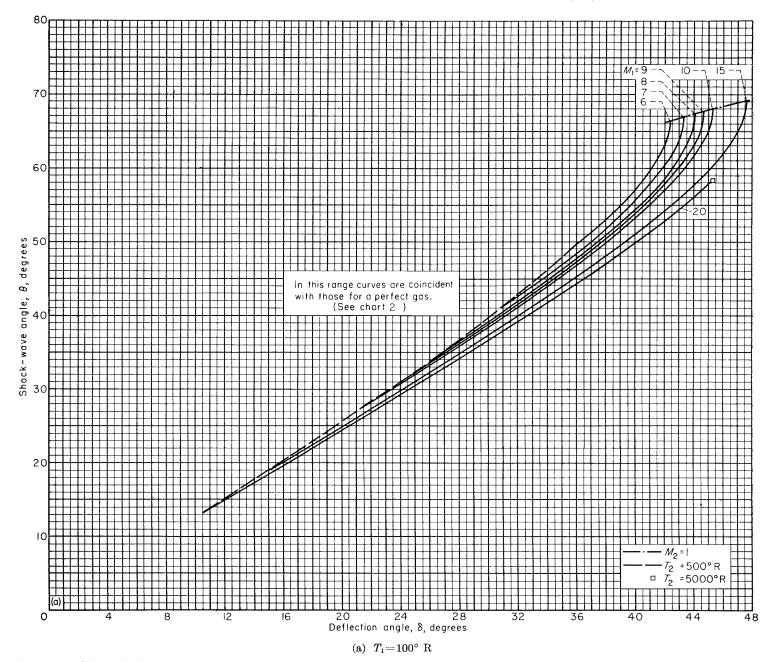
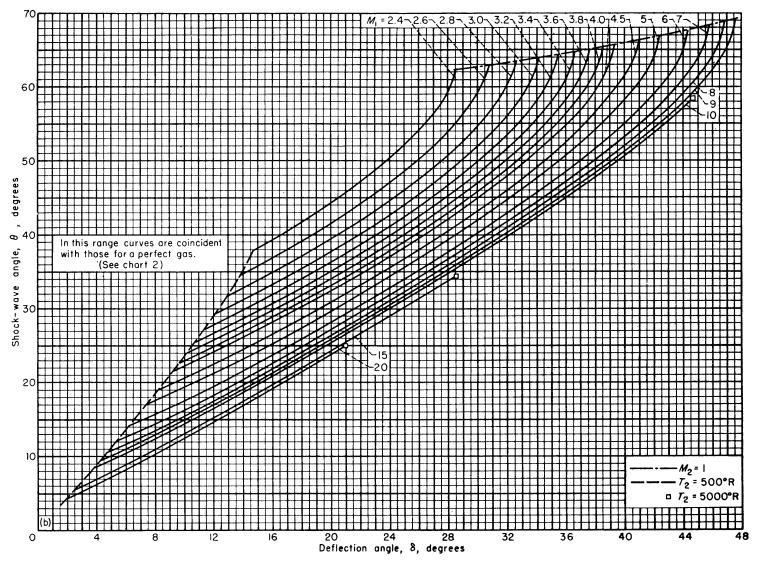
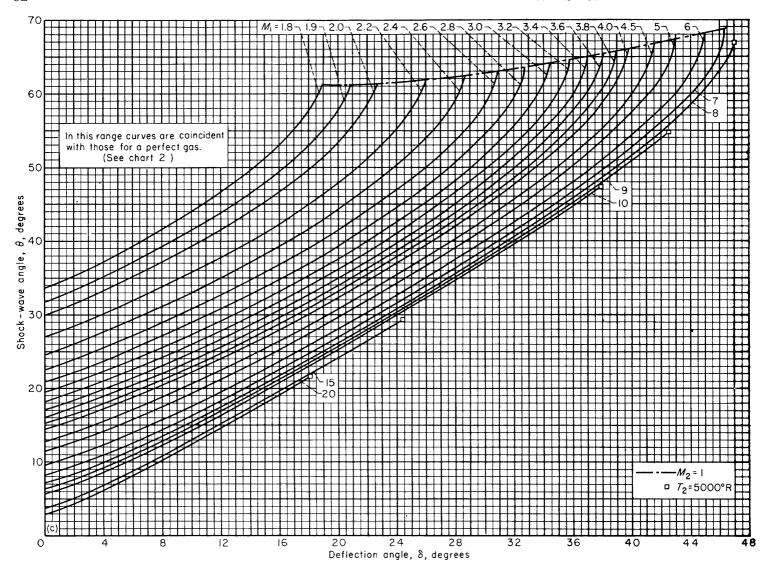


Chart 21.—Effect of caloric imperfections on the variation with flow-deflection angle of the shock-wave angle for a weak oblique shock wave.



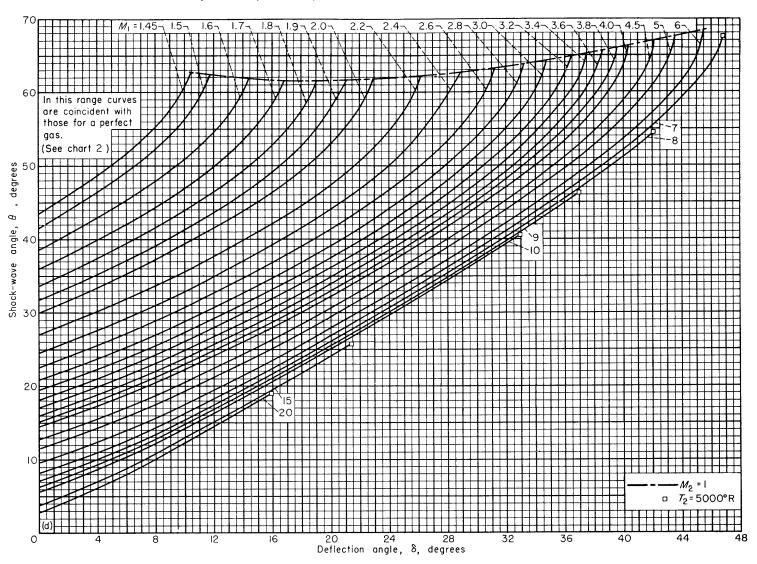
(b)  $T_1 = 390^{\circ} \text{ R}$ 

CHART 21.—Continued



(c)  $T_1 = 500^{\circ} \text{ R}$ 

CHART 21.—Continued



(d)  $T_1 = 630^{\circ} \text{ R}$ CHART 21.—Concluded

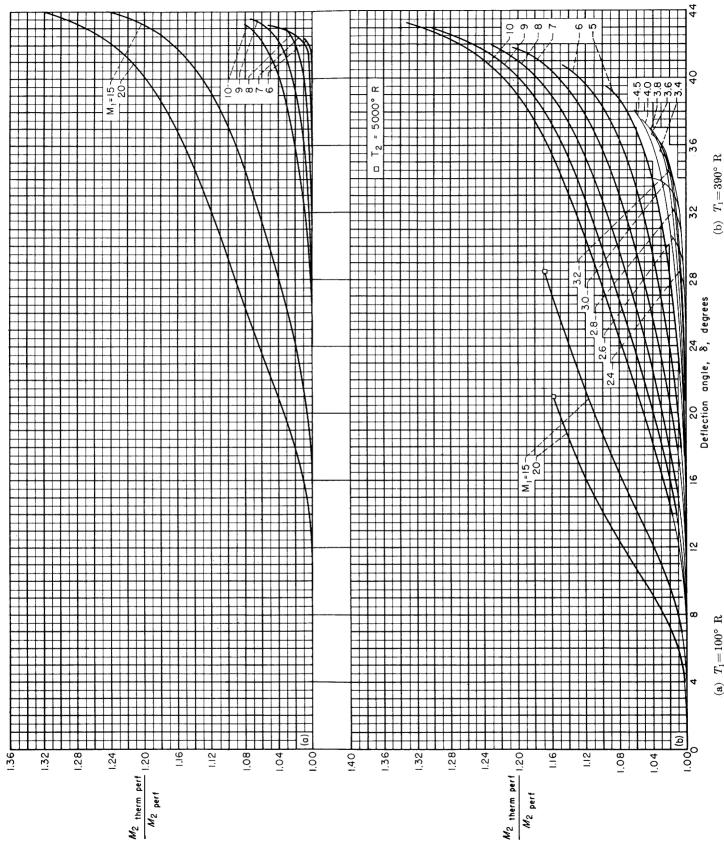
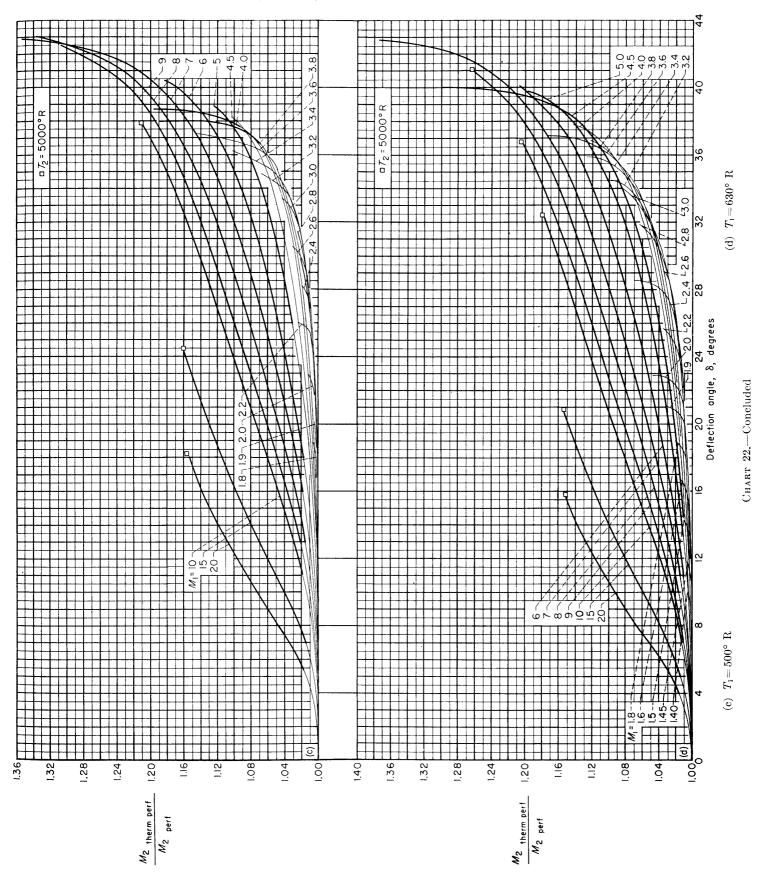


CHART 22.—Effect of caloric imperfections on the variation with flow-deflection angle of the Mach number downstream of a weak oblique shock wave.



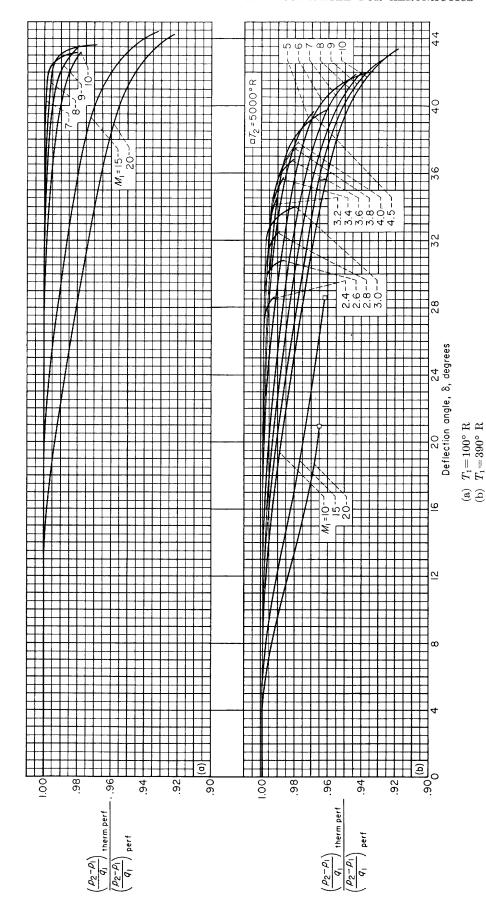
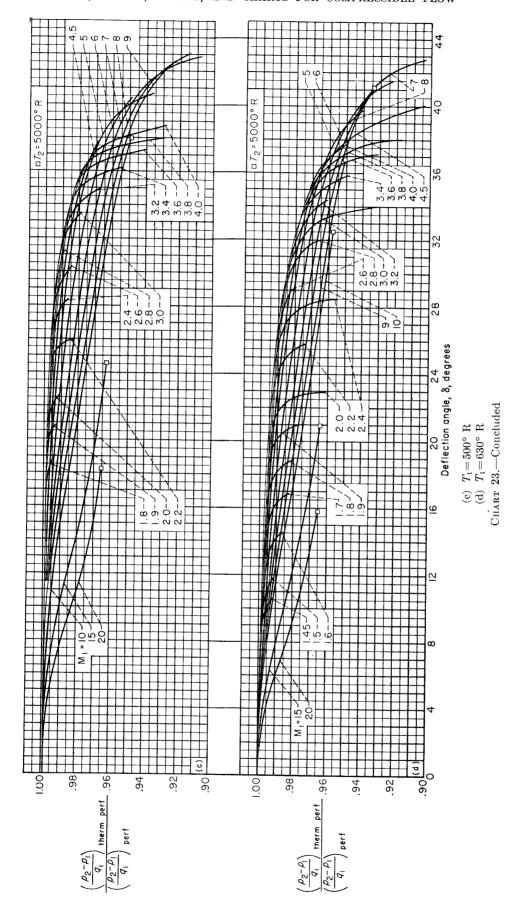


CHART 23.—Effect of caloric imperfections on the variation with flow-deflection angle of the pressure coefficient across a weak oblique shock wave.



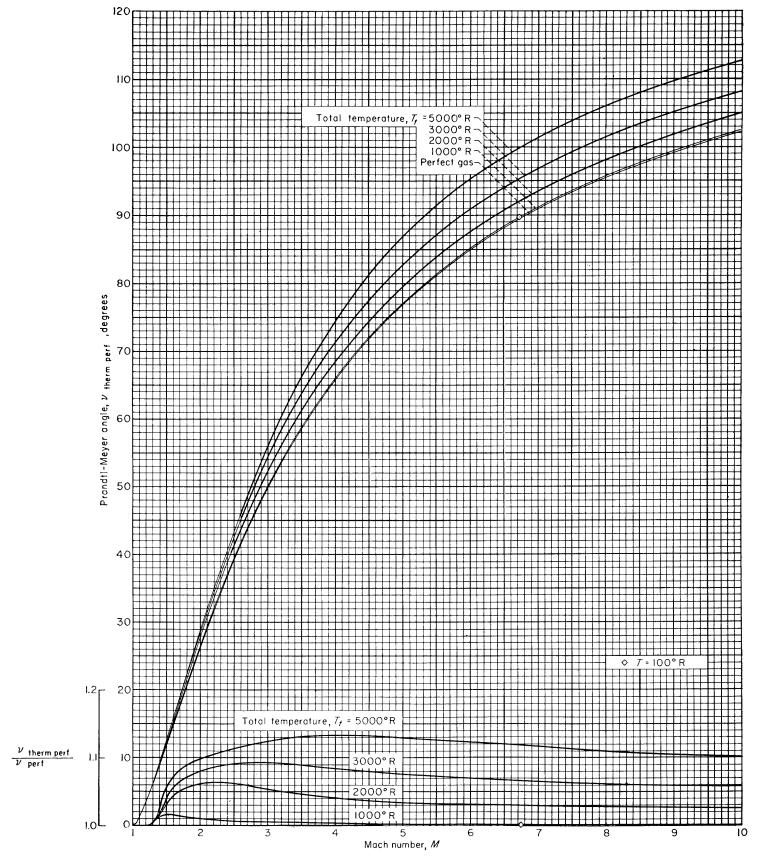
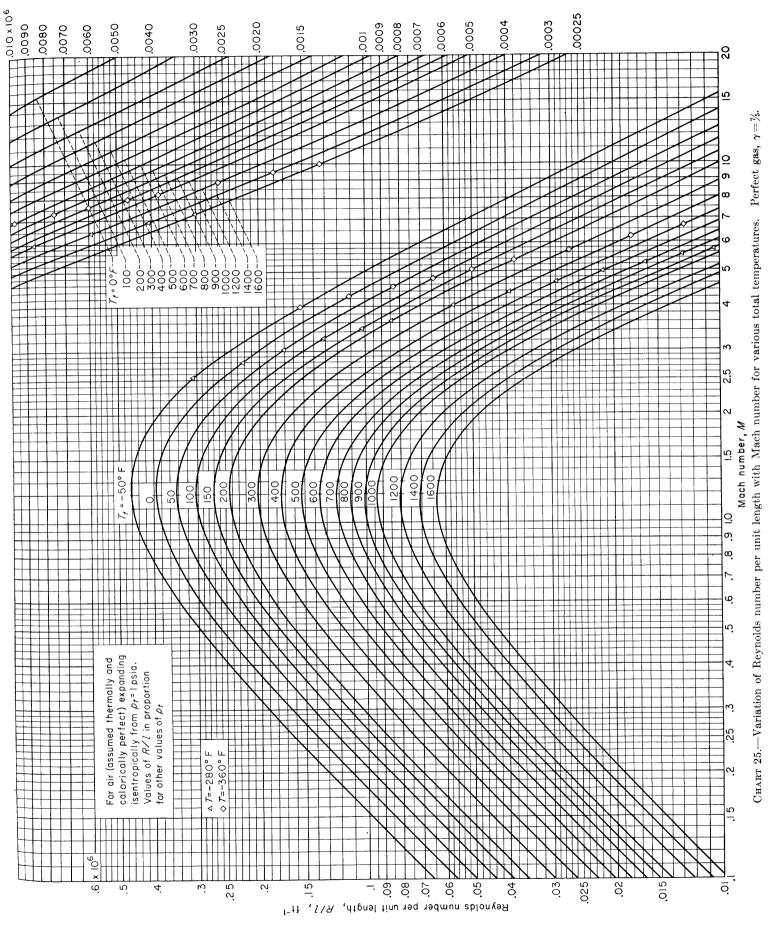


Chart 24.—Effect of caloric imperfections on the Prandtl-Meyer angle.



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